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FOR RESEARCH & DEVELOPMENT MANAGERS

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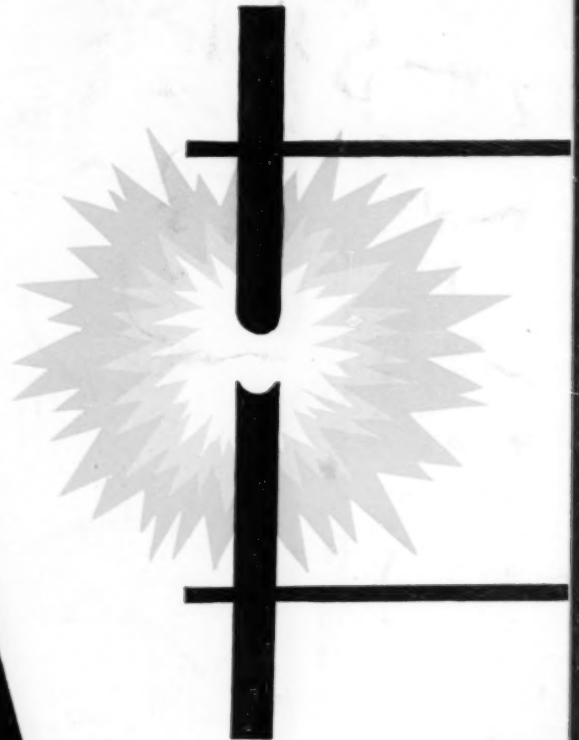
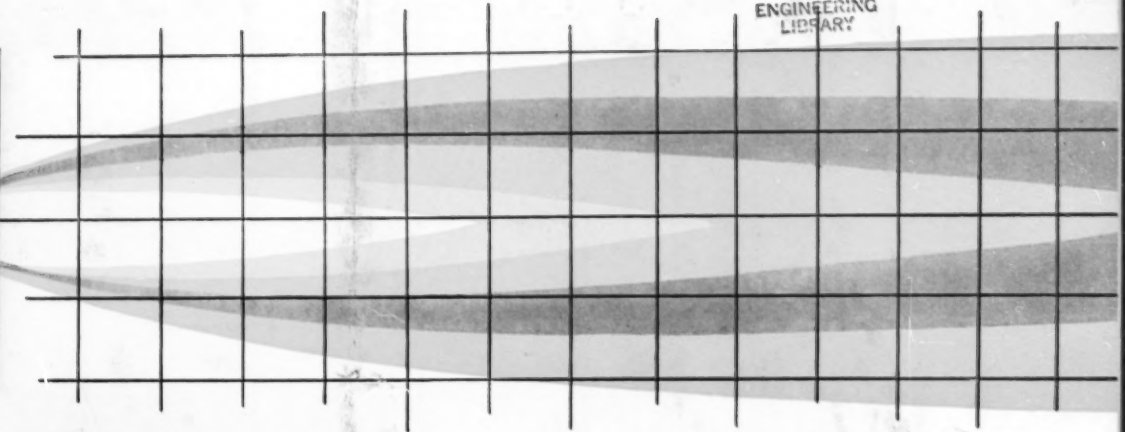
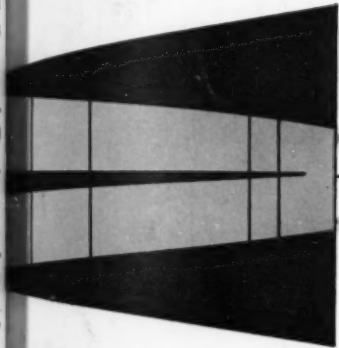
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# RESEARCH & ENGINEERING

the magazine for  
research and  
development managers

AUGUST 1956

VOL. 11 NO. 8

Publisher William H. Relyea, Jr.  
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## FEATURES

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*And the future could be tomorrow. Enough has been uncovered in this new area to predict that from it will come a significant portion of tomorrow's new products and processes.*

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*A challenge to engineers: how quickly can you put to use the newly discovered laws of high temperature technology?*

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RESEARCH & ENGINEERING is circulated to men in charge of industrial research, development and design departments in all branches of industry and in government research installations. Subscription: U. S. A. and Canada, \$18.00 annually; other countries, \$28.00 annually. Single issue \$1.00 when available. Published monthly by The Relyea Publishing Corporation, William H. Relyea, Jr., President; Harold G. Buchbinder, Vice President, Executive, advertising and subscription office; 103 Park Avenue, New York 17, N. Y., LEExington 2-0541. Editorial office: 71 South Street, Stamford, Conn., FIreside 9-7721. Unsolicited manuscripts must be accompanied by return postage. Although all reasonable care will be taken the editors assume no responsibility for their safety or return. All editorial communications should be sent to the Stamford Office. Published and accepted as controlled circulation publication at Orange, Conn. Copyright 1956, The Relyea Publishing Corporation.

## from the publisher

Last June 25, 26 and 27 Editor Buchbinder covered a symposium on high temperature technology at Berkeley, California. Sponsored jointly by Stanford Research Institute and the University of California, the symposium was supported by the Air Force Office of Scientific Research, U.S. Air Research and Development Command; the National Science Foundation; the Office of Naval Research; and support for foreign participation by the Office of Ordnance Research.

The participation of these government agencies is an indication of the current and future importance of high temperature work; evidence of its interest and importance to industrial concerns can be had by the fact that the meeting place had to be changed to larger quarters three times as the preregistration forms began to come in to symposium headquarters. Originally, the sponsors planned on a meeting of about 250 men—they hoped. When the registration went over 400, previous plans were scrapped, and when the total edged toward 600 they were again altered. Actual registration was closer to 700, with registrants from every conceivable area of industrial research development and engineering fields.

Because of the tremendous interest in this subject, and because the meeting was productive of so much that was new, advanced and of immediate importance in so many different aspects of product and process development, we have decided to devote our entire feature section of this issue to subjects presented at the symposium and to the individual comments our Editor recorded on the sidelights.

This then, is the reason for the unusual imbalance of this month's editorial content. Normally our editorial pages are divided as follows: 40% to advances in industrial technology; 40% to problems and their solution in the management of industrial research, development and engineering departments; and 20% to news and events or products relating to both areas of interest.

Because of space limitations, our intensive coverage of the meeting still does not permit us to publish complete

details of everything worthy of being called to your attention. For example, many of the papers included detailed mathematics, bibliographies, charts, diagrams and tables, some of which will be published for the first time. For this reason the symposium proceedings, to be published by Stanford Research Institute (\$5.00) either late in September or early October, will undoubtedly be one of the best up-to-date reference sources of who is doing and has done what in high temperature technology. You can order your copy by writing to Charles A. Scarlott, Stanford Research Institute, Menlo Park, California.

Some other items of interest. Dr. Merritt A. Williamson, who conducts our monthly column on research administration, started a new job on August 1. Formerly manager of the Research Division of the Burroughs Corporation, and special lecturer on research administration at the University of Pennsylvania, Dr. Williamson is now Dean of the College of Engineering and Architecture at Pennsylvania State University. In addition to his new duties, Dean Williamson will continue to write his monthly column on case histories and comments on the administration of research.

Starting this month, Dr. Ronald C. Vickery, an international authority in chemistry, joins our staff as a contributing editor. On the average of every other month we shall be publishing his feature-length articles on important areas of chemical research and development.

Occasionally we like to remind you, our reader, that our single most important objective is to give you what you want. While we are continually conducting readership research of our own, including surveys from time to time, we still depend upon your individually inspired comments and suggestions. But one word of caution. Normally any letter addressed to an editor or a magazine is legal grist for publication in Letters to the Editor. Thus, if you have comments or suggestions by all means send them in, but please tell us if you do not want us to bring your thoughts to the attention of our readers; otherwise they could be selected by editors for publication in our "Letters" column.

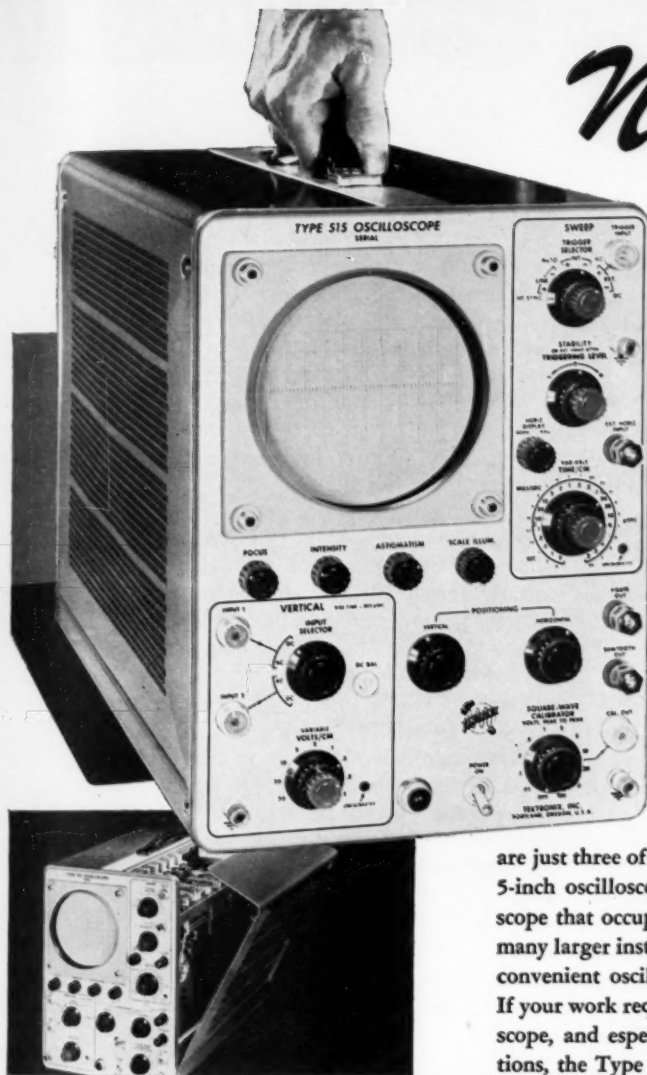
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# New



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FOR MORE INFORMATION CIRCLE NO. 2 ON PAGE 48

## Big Boom in Sonics



Although modern research and development efforts have not, as yet, been able to reproduce Joshua's feat—destroying the walls of a town by a loud blast on a trumpet—it is blasting away at the barriers that are preventing man from gaining a better understanding of the world in which he lives. Hardly a scientific or engineering area exists to which sonics has not begun to contribute.

Born in the early 1930's, this new field has progressed to a business which should result in a yearly turnover of two billion dollars worth of equipment in the very near future, in spite of the fact that a good deal of work remains to be done to fully understand and exploit the industry. Most of the difficulties stem from the problems in the design of suitable transducers for the generation of vibrations. The application of high power acoustic waves to a particular problem usually requires an efficient converter and most efforts are being directed toward this end. Transducers currently take a number of forms ranging from simple whistles to elaborate electrical generators using the piezoelectrical effect and employing large radio tubes to provide the electrical energy to drive them. The current tendency is to specifically design a transducer for a particular application; examples: ultrasonic dental drills, ultrasonic soldering irons for normally unsolderable metals such as aluminum, sonic scrubbing machines for cleaning purposes, siren generators for the removal of solid particles in gas streams of chemical processing plants or in stack gases and others of similar types.

Last month, more than 500 of the world's leading authorities on sound and noise took part in the second international congress on acoustics in Cambridge, Mass., under the sponsorship of Harvard University and the Massachusetts Institute of Technology. The meeting was the largest technical meeting on acoustics and sonics to date. For the research and development engineer not normally working in the field of physical acoustics and sonics, perhaps the most interesting aspect of the meetings were those papers presented on acoustical studies of matter, the propagation of sound, and the application of acoustics to technical problems.

## Mechanical vs. Electronic Generators

At present the electronic generators dominate, but the leader in ultrasonics has confided to RESEARCH & ENGINEERING that mechanical generators may gain the ascendancy over electronic ones in a short while. Such a mechanical generator with a great deal of promise was discussed at the congress. Vladimir Gavreau of the Centre de Recherches Scientifiques, Industrielles et Maritimes, Marseille, France, described a whistle-like generator with no moving parts. It is a more general form of the policeman's whistle taking the shape of a double toroidal resonant cavity fitted with an annular exponentially shaped horn. One laboratory model has a fundamental frequency of 20,000cy and a powerful ultrasonic harmonic of 460,000cy. Another French generator without moving parts is called the "Multiwhistle R. B." Described by E. Brun of the University of Paris and R. M. G. Boucher of the French Air Ministry, this generator attains an efficiency of 15 to 20 percent. Emitting at 33,000cy it can rapidly dissipate fog. According to our informant the French have quite a lead over the United States in the development of mechanical ultrasonic generators.

Potentially, the mechanical generator has a far higher efficiency than the electronic type, with its two percent efficiency. If a manufacturer already has a source of compressed air available, the mechanical generator is particularly attractive. Another type of mechanical generator would use ordinary tap water to produce ultrasonics in a manner similar to the "water hammer" effect in heating systems.

## Chemistry and Chemical Processing

Chemical effects produced by strong ultrasonic waves in aqueous solutions are peculiar phenomena that have puzzled investigators for a long time. Olle Lindstrom, of the Royal Institute of Technology, Sweden, called attention to an analogy between the cavitation process and one of the most dramatic manifestations of nature: the thunderstorm. The characteristic phenomenon of the two processes is constituted by electrical discharges and the associated chemical reactions set up are essentially of the same nature. The origin of the electrical energy seems to be electrical charge of water surfaces, in the macro process the surface of small droplets of water in air and in the micro process the surface of small cavities in the continuous water phase. Lindstrom predicted the possible use of cavitation in chemical processing would follow two different routes: utilization of the true chemical effects caused by the free radicals and utilization of the "micromechanical" action. The first route includes oxidation, reduction and polymerization reactions. And here the ultrasonic approach has to compete with for example the use of ionizing radiation from radioisotopes for the same purpose as well as already well established pure chemical procedures. The micro-mechanical effects

**PUBLISHER'S NOTE:** The message on the opposite page is a paid advertisement of the Perkin-Elmer Corporation, Norwalk, Conn. For more information circle 7 on page 48.

# G. M. BASFORD CO.

## Call Report

Date: March 23, 1956  
Place: Shulton Fine Chemicals Division  
Client: The Perkin-Elmer Corporation, Norwalk, Connecticut  
Purpose of trip: To get story on Model 21 Spectrophotometer in fine aromatic chemicals and essential oils analysis  
From: F. Messner  
To: P. Wilks, C. Miller, P. Slawter, C. Perrin, J. Craig

I interviewed Stephen P. Joffre (Research Associate), and Nancy Scelba (Spectroscopist) at Shulton's laboratory in Clifton, N. J.

Joffre said that probably their chief use of the Model 21 infrared spectrophotometer is to determine various isomers as they occur in natural oils. Since isomers are identical in elemental and functional group composition and differ only in structure, they do not readily lend themselves to analysis by chemical methods.

A very good example is a quantitative analysis which Shulton runs involving safrol and isosafrol. They buy *ocotea cymbarum*, a sassafras-like oil from Brazil. It contains a high percent of safrol. Shulton first runs an analysis on the raw material to determine how much safrol it contains. Then they isomerize the safrol and run an analysis with the Model 21 to determine how much of the material has been converted to isosafrol. Joffre said he knows of no direct chemical method whereby this could be accomplished. Another example of isomer identification is in determinations of eugenol and isoeugenol.

Joffre said that Shulton regularly uses their Model 21 in development work. Shulton has found a way to synthesize Rhodinol, which is a mixture of two isomers of a ten carbon alcohol (Rose alcohol). The synthetically prepared material sells at a much lower price than the naturally derived material which comes from geranium oil. Shulton starts with citronellol, and uses the infrared instrument to observe shifting of the double bond. They compare citronellol before and after isomerization and confirm the ratio of the isomers to each other. What the IR did in this development, in effect, was to provide a physical means of proving that what they had was a true Rhodinol, synthetically made, rather than a compounded Rhodinol. (Attached is a technical data sheet which explains more about Rhodinol in detail).

Joffre also said that Shulton uses the P-E instrument in the routine work of tracing the course of reactions in organic research and development. He uses it to check whether or not in esterification there is any free acid or free alcohol left. He can follow the course of the reaction by noting the wavelength shifts in the spectra which reveal changes in strong functional groups. Determining an ester by wet methods might take 2 or 3 hours. Infrared can tell in 10 or 15 minutes.

I asked Mr. Joffre what he thought of the instrument. He said that he had used a Model 21 in several places before, and it was the one for him. He mentioned its ease of operation and versatility. He said that Shulton has had the Model 21 since April of 1953.

I asked him about Perkin-Elmer service and he said it is excellent. Joffre said the Perkin-Elmer serviceman stops in whenever he is in the area without being called and checks to see if everything is all right. Joffre also said that they went up to Norwalk 2 or 3 times to pick up some fine points on operation and that they had called Norwalk on several occasions when they had special problems. Joffre said that P-E service people know their instrument inside and out. He added that the instru-

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FOR MORE INFORMATION  
CIRCLE 4 ON PAGE 48

fects of cavitation have potential uses for depolymerization, emulsification, homogenization, extraction, dispersion, descaling, and/or cleaning of solid surfaces.

## Plastics With Unusual Properties

The most promising potential uses of cavitation in chemical processing seem to be typical ultrasonic applications. The combined effects of chemical and micro-mechanical action belong to this specific category. Simultaneous polymerization and depolymerization by cavitation is likely to yield plastics with unusual properties. The cleaning action of cavitation is already utilized with success in electroplating. The same effect may also be of very great importance as an aid in speeding catalytic reactions where the surface of the catalyst is blocked by the reaction products which may be removed by the cleaning action cavitation during the reaction.

The ability of ultrasonic waves to generate gas nuclei in a homogenous process may have great future applications in more special connections. One obvious possibility of this process is, however, to eliminate bumping in industrial distillation.

Our knowledge of phenomena associated with materials in the solid and gaseous state is far above our knowledge of the structure of materials in the liquid state. To improve current theories, some research men have begun to study the behavior of liquids under conditions that might possibly show their structural characteristics. Present research uses the propagation of sound to investigate structural changes taking place in various liquids when they pass from the normal to the super-cooled regions. Viscosity measurements have already shown some polar or ionic liquids, structure changes like association of molecules, must occur at the transition point between the two zones. The changes in sound philosophy are very small and previous research in some of these liquids fails to show a detectable effect.

Alphonso Barone, Gualtiero Pisent and Daniele Sette of Italy reported the use of a high precision interferometer used to measure the sound velocity in menthol and salol. Their interferometer uses a Schlieren method to make the interference field of the two planes sound waves visible. One of them propagates in the liquid under measurement between the quartz ~~salt~~ <sup>plate</sup> and a movable reflector; the other in an auxiliary transparent liquid. The two waves interfere at a very small angle in the auxiliary liquid. The set up permits them to observe a picture on a screen which takes the same configuration when the reflector is shifted by halves of wave lengths. The measure of velocity in salol and menthol has shown a sudden change of velocity in the transition region between normal and supercool liquids. For the super-cooled liquids, there is an increase of velocity in the salol and a decrease in menthol. The behavior seems to indicate to these men that a complete reorganization of the liquid in a new structure takes place at the transition point.

N. Collet of France has been studying the problem of dispersing agglomerates in liquid. Old conventional dispersion processes generally do not satisfy the physical conditions required for obtaining solid particle suspension in liquid, mainly when distribution by isolated grains of previously highly agglomerated particles is required.

## Improving Heat Transfer Ultrasonically

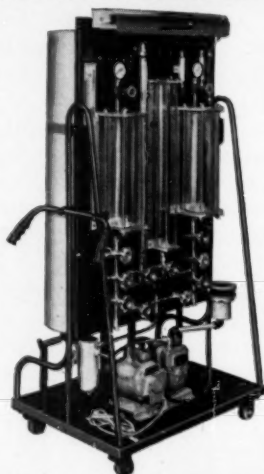
Heat transfer from a bare nichrome wire was speeded up four times by vibrating it according to Robert Lemlich of the University of Cincinnati. He reasoned that the blanketing film around the wire was cut down, and achieved the

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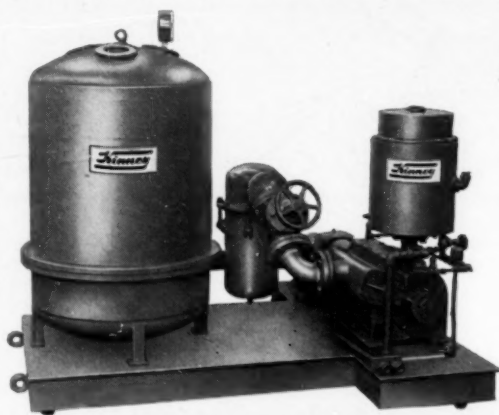
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FOR MORE INFORMATION CIRCLE 5 ON PAGE 48

same effect in a small heat exchanger by introducing acoustic vibration from a musical reed placed in the stream. A large ultrasonic generator could produce the same effect in the big heat exchangers used throughout industry. If the reduction in size of heat exchanger for a specific function is enough to compensate for the cost of adding a sound source, this could be a widespread use for ultrasonic generators.

### Electrolytic Separation of Metals

Albert Roll of the Max Planck Institute for Metallabscheidung of Germany has been working on obtaining metals by electrolytic preparation. The possibility has been established for a long time. Roll has been successful on a small scale, but lacks the ultrasonic generators that would permit experiments on a large technical scale to determine the feasibility of approaches for commercial application.

On the opposite end of the pole, Hermann Oberst reported that Germany and other European countries are using suitably composed high polymers as highly effective damping coatings of sheet level structures. These high polymers diminish the flexural vibrations of thin plates of metals and thus reduce the disturbing noises of these structures. The high polymer materials must have a high internal damping and at the same time a sufficiently large stiffness.

### Extending Non-Destructive Testing

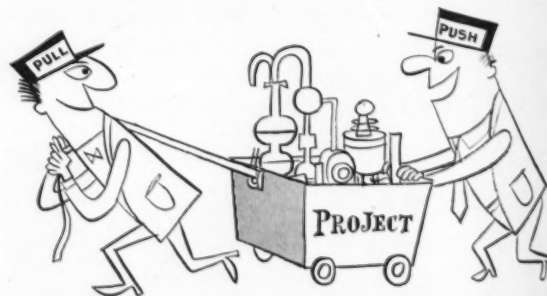
The use of ultrasonics to detect gross defects in metal products is well known. Wilfred Roth of the Roth Laboratory for Physical Research in Hartford, Conn., believes that more refined tests such as determining the depth of hardness and the measurement of internal strains in a piece

of metal can be done ultrasonically. Analysis of the complex effect of the metal formation on the ultrasonic crater may be beyond human capability. Roth suggests replacing the human observer with a highspeed computer.

In the actual research and development of new materials rather than in the production stages, ultrasonic testing could give a dynamic method of measuring elasticity constants and damping factors. Robert Cabarat of the Experimental Laboratory of the National Conservatory of Arts and Trades, Paris, France, described an ultrasonic method for measuring the above properties. Measurements can be made over an unlimited range of temperatures.

Most of the papers at the congress dealt with the nature of sound and its propagation. A number considered the destructive as opposed to the useful effects of sound on both humans and materials. In discussing structural fatigue due to jet noise, Alan Powell of the University of Southampton in England said that the damage is caused by the rapidity of load application and not by the intensity of pressure fluctuations due to acoustic vibration. His closing remarks deserve quotation: "Now that the question of aircraft noise is affecting the aeroplane itself and causing the designer much effort to ensure maintenance of safety standards, the public may rest assured that the designer will avoid as much noise as possible."

### Perception in the R & D Team



Each member of a research and development team should appreciate the roles of every other member of the team for maximum efficiency. With a better appreciation of the roles of all members of the team, the research worker will be able to accept not only their behavior but also his own as well. According to Dr. Irving Lorge, Professor of Education at Teachers College, Columbia University, to the degree that the R & D worker is aware of the range of tasks, from technical competence to managerial skill, to that degree he will be able to have more adequate perceptions of himself in the role of others.

In a talk at the recent conference on Industrial Research at Harriman, N. Y., sponsored by the Department of Industrial and Management Engineering of Columbia, Dr. Lorge also advocated teaching technical people some of the basics of management. Dr. Lorge maintains that the relations of the R & D worker with his peers and with his supervisor depend not only upon the individual's traits and tendencies but also upon what he has learned from experience. The training of the research scientist, he said, must therefore envisage the probability that each will

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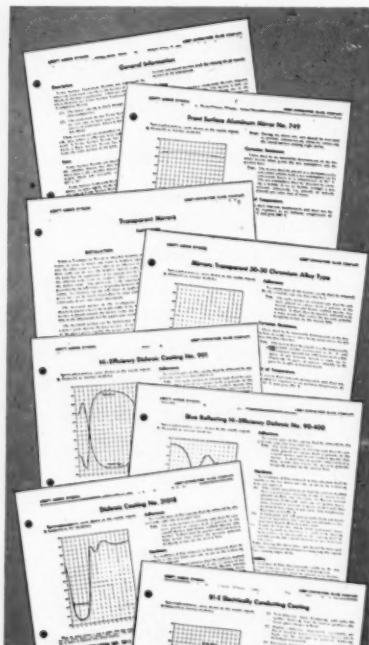
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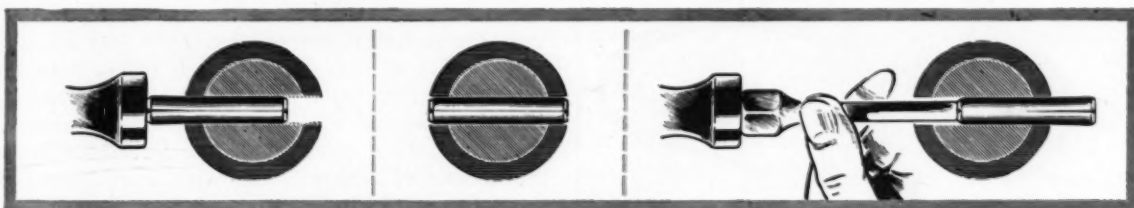
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## MATERIALS AND SIZES

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FOR MORE INFORMATION CIRCLE 3 ON PAGE 48

attain some managerial level requiring supervision of people, decisions about scientific programs, and the budgeting of time, money and effort. Thus, every university teacher of a science and every research director has a responsibility for orienting research personnel for such an eventuality. Even though not every research worker can attain (or would wish to accept) such supervisory responsibilities, Dr. Lorge feels that all would benefit by getting a more valid perception of each other's tasks and of each other. The objective of both the universities and industry should be to increase the range of usefulness of R & D people over their work careers.

Beginning with the techniques of training technical personnel, Dr. Lorge developed the psychology behind the above assertions. In the fields of natural science and social science, the university teacher tends to emphasize the minutiae of technique and methods in acquiring new knowledge. In training in science, the student is indoctrinated in the role of the research and development worker. The

longer he trains for and works as a researcher, the more likely he is to think and act like a researcher.

More and more, said Dr. Lorge, the technical man acquires the attitudes, interests, appreciations and motivations of his kind. He deliberately adjusts his standards and mode of living to the roles expected of a scientist or engineer. To a large extent, his hobbies and avocational interests are determined by what he thinks other R & D workers do along these lines. He appreciates the acclaim of his scientific peers for his papers more than he appreciates increments in his earning capacity. Dr. Lorge said he may even deprecate the "devilish compact" by which a technical man sells himself as an administrator.

The R & D director, however, has a new set of adjustments to make. Some, in the area of knowledge and technique in his own field, are easy to make. Yet the new status brings new problems of relating to personnel for whom he has managerial responsibility. Some of these adjustments may involve a conflict between his new role, his older role, and his sense of self.

Because of underemphasis in his school and work career upon the roles of the administrator, the scientist or engineer sometimes fails to gain an understanding of what management can and must do. When he is placed in charge of a R & D enterprise, he may not only lack understanding of his new role but may also have negative feelings about it. According to Dr. Lorge, the conflict in him is between his perception of his role as an R & D worker and his perception of his new role as R & D administrator.

#### Maturity and the Role-Role Conflict

Dr. Lorge feels that the "role-role" conflict is frequently enhanced by the changes maturity brings. In his maturation, the technical person may have learned to prefer to operate with wisdom and prudence, rather than with cleverness and daring. And with maturity, his scheme of values may have been so strengthened that he cannot easily shift the frame. As a consequence, he interprets and evaluates the actions of others by his own knowledge and motivations. His ability to emphasize and relate with his staff and with management may have become overspecialized by education and experience.

Some role-role and some "self-role" conflicts are the inevitable concomitants of growing into maturity. Some frustrations accompanying shifts in status and in role may be relieved by giving the administrator an understanding of himself and his development. Dr. Lorge thinks that some appreciation may come by changing the ways in which scientists and engineers are educated.

#### AEC Scientists Capture the Free Neutrino

The free "neutrino", a particle without electrical charge and vanishingly small mass, has been detected by the AEC's Los Alamos Laboratory. The neutrino is the second atomic particle to be discovered in AEC labs in less than a year. Last October, scientists at the University of California Radiation Laboratory identified the antiproton.

Neutrinos are so penetrating that they will pass through billions of miles of solid matter. Consequently, the detector developed by the Los Alamos scientists is of extraordinary design. In it more than 100 gallons of ordinary water containing a dissolved cadmium salt served as a target for the neutrinos coming from the reactor. This target was "watched" by a scintillation system which contained over



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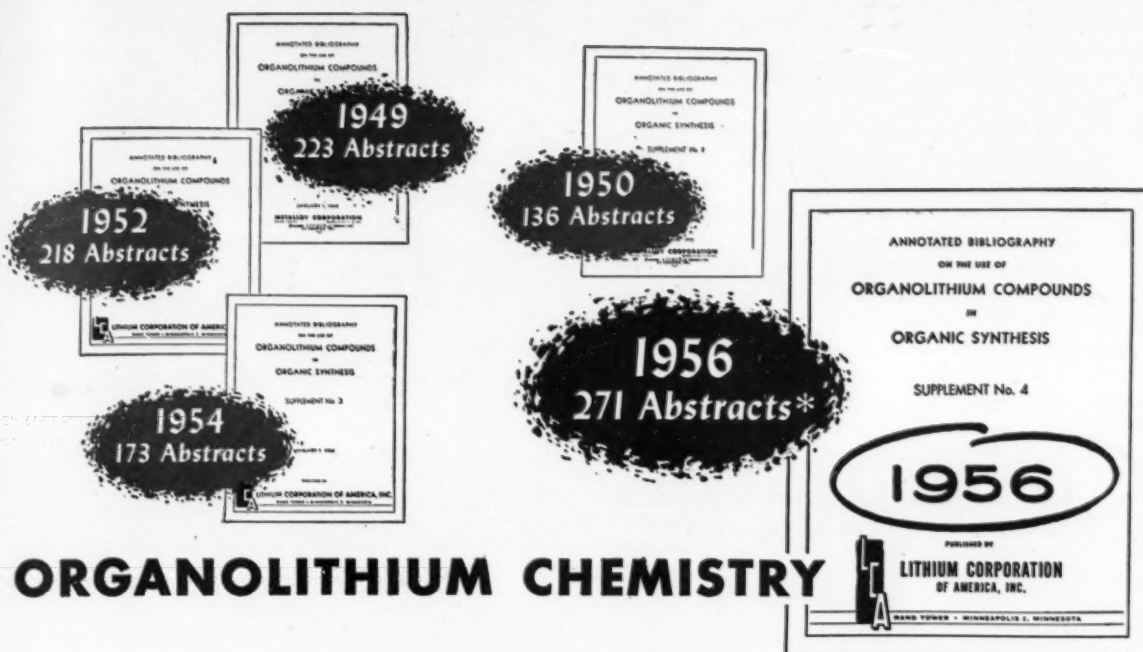
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CIRCLE NO. 8 ON PAGE 48



## ORGANOLITHIUM CHEMISTRY

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FOR MORE INFORMATION CIRCLE NO. 9 ON PAGE 48

1000 gallons of a sensitive liquid and 330 large photo multiplier cells. Despite its huge size and the many billions of neutrinos from the reactor which passed through it each second, only a few neutrino captures were observed in the target water each hour.

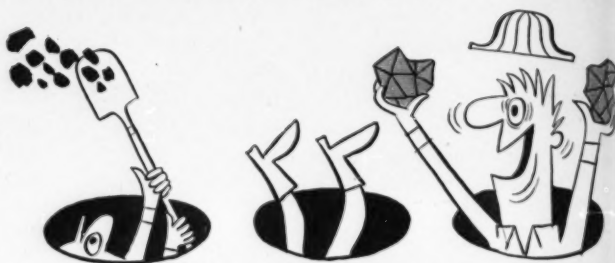
The scientists behind the discovery, led by Frederick Reines and Clyde Cowan, Jr., believe they first observed the neutrino in the Spring of 1953 when they set up a large scintillation system at the Hanford, Washington plant of the AEC. Although the Hanford experiments indicated the neutrino's existence as a particle in the free state, the evidence was not entirely conclusive. The physicists then returned to Los Alamos where they devised the more complex detecting system. The scientists now feel that they have checked each important characteristic of the neutrinos caught in their detector.

### Reversing Beta-Decay

This discovery marks the first time that man has knowingly caused a direct reversal of beta-decay. In the present experiment, normally stable protons (hydrogen atoms in the water) were made to absorb a neutrino, emit a positive electron, and become neutrons. Thus a particle with the expected properties of the neutrino has been detected in an inverse beta-decay reaction, the theory of Fermi and Pauli may be considered as proved, and nuclear scientists may accept with some confidence the further theories which have been developed involving the neutrino.

No immediate practical application of the discovery of the neutrino is known at the moment. But Dr. Willard F. Libby, Acting Chairman of the AEC, feels that the discovery is of great importance, since progress in utilizing nuclear energy for human welfare depends upon advances in basic knowledge of nuclear forces. Discovery of the neutrino, he says, should help to shed light on the nature of the "glue" which holds atomic nuclei together.

### British Chemists Study Metals Valuable in Atomic Energy Development



Chemical research programs undertaken during 1955 by Great Britain's Department of Scientific and Industrial Research covered a wide range of subjects, with particular emphasis on the extraction and concentration of metals valuable in the development of atomic energy. Nearly one-quarter of the staff of the Chemical Research Laboratory of the Department is engaged in the study of minerals, ores and other materials for the United Kingdom Atomic Energy Authority.

### Extraction of Uranium and Other Precious Metals

The Laboratory's Radiochemical group has intensified its efforts in the study of chemical extraction and concentration of metals. Samples of uranium ores from various parts of the world have been used to develop extraction methods on a large scale. Processes investigated include those which involve leaching followed by selective precipitation or recovery by ion-exchange or by solvent extraction.

The usual way of recovering metal from an ore by ion-exchange is to treat the ore with a solution that dissolves the metal, the metal being recovered from the filtrate after insoluble matter has been filtered off. A process in which the filtration step is left out is being investigated. The resin in

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suitable form is added to the pulp of ore and extracting solution. The ion-exchange can later be removed from the pulp mechanically and passed to an eluting circuit.

#### Major New Process for Gold Recovery

A new process for recovery of gold from cyanide solutions has been developed which could revolutionize gold recovery technique. Gold and Silver can be selectively adsorbed from a normal gold mill pregnant liquor by certain weak base ion-exchange resins. They can then be easily eluted by a relatively inexpensive reagent from which the ore can be recovered by electrolysis. The gold producing industry is showing great interest in the new process although considerable research is needed before the method can be adopted commercially.

#### Separation of the Rare Earths

Partly because they are no longer rare and partly because of atomic energy interests, the rare earths are attracting increasing attention in Britain. The Laboratory is studying methods of separating the rare earths and of producing pure compounds. The ultimate goal is to produce pure metals. Ion-exchange methods are being used and an apparatus has been constructed capable of handling kilogram quantities of the mixed earths.

#### Purification of Semiconducting Elements

Extensive research on semiconductors has stimulated much work on preparation of ultra-pure specimens of the elements showing such properties. Methods of preparing these materials are being studied by the Laboratory.

#### Cellulose in Paper-strip Chromatography

A notable development in chromatographic techniques during 1955 was the discovery that the utility of paper chromatography can be greatly increased by the use of chemically modified forms of cellulose. For example, phosphorylated cellulose can adsorb large quantities of certain metals from very highly acid solutions where normal ion-exchange resins would be ineffective.

The cellulose material can be used in the form of paper for strip chromatography or in the form of a floc for use in columns. A tendency for the material to deteriorate in storage has been overcome, resulting in a product sufficiently stable for practical purposes.

#### Ion-exchange Paper

Conventional methods for separations using ion-exchange resins are often unnecessarily elaborate for qualitative analysis. A simple method has been devised for preparing paper with ion-exchange properties in which a finely divided ion-exchange resin is incorporated in the cellulose pulp. The ion-exchange paper prepared from the pulp should be of value in qualitative analysis. It can be used for separating mixtures of cations (or anions) using techniques similar to those in conventional paper chromatography.

#### Bacterial Breakdown of Organic Compounds

Large quantities of aromatic substances are presently running to waste in Britain. Some of these aromatics are used in sheep dips, plant-control chemicals and insecticides; these are broken down microbiologically during use and in the soil. The Laboratory feels that it would be valuable to have more information on the actual processes of bacterial breakdown of these compounds to improve existing products, produce new ones from materials of little value at present, and discover reactions useful in the synthesis of compounds presently difficult to produce by conventional chemical methods.

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Dispersal of target cities like New York, Chicago, Detroit and Pittsburgh may be the only defense against future intercontinental missiles, according to the Federation of American Scientists, 2000-member group of scientists and engineers with headquarters in Washington, D. C. FAS says that dispersal will not only save lives but, by decreasing our vulnerability to attack, may make such attack less effective and therefore less likely.

In supporting an extension of the Defense Production Act of 1950, FAS warned that "the nation's defense program is out of balance because dispersal of target cities is not proceeding fast enough". The defense measure discourages the concentration of productive facilities within limited geographical areas which are vulnerable to attack by an enemy of the United States. FAS's contention is that "we are spending many billions each year on military weapons but hardly a cent on dispersal—the one defense measure that has a chance of lasting effectiveness. On the other hand, "conventional military arms become out-of-date in a short time and must be replaced by new ones at great expense".

If these proposals are carried to their logical conclusion and implemented, they could mean lower military budgets and therefore less money spent on R & D by the military. At present perhaps half the money spent on research and development each year in the United States is expended by the Department of Defense.

### Motivation: Father of Invention

Necessity, said a wise man, is the mother of invention. In the view of Fairchild Camera and Instrument Corporation, motivation may be the father as a result of a new policy affecting all technical personnel.

Recognizing that the success of research and development depends on inventive talent, the company has set up a plan for awarding a plaque for "the best patent of the year" together with a personal gift. The award will be presented at an annual banquet held by the company for all of its R & D personnel.

In the new program, all patent applications will receive publicity through the employee newspaper and through circulation of copies to top company officials and engineering personnel. Certificates suitable for framing and visits to the inventor's workplace by the Board Chairman are other facets in the program for increased recognition. In addition, when the company decides not to act on a patent after due consideration, title reverts to the initiator.

This program for stimulating inventive motivation at Fairchild is similar to programs at other manufacturers, notably RCA. A number of firms also have informal plans where engineers are given bonuses for significant patents or discoveries.

## Glycerine Influence on Diffusion-Controlled Reactions

Glycerine has a marked influence on the reaction rates of diffusion-controlled chemical reactions, it has been discovered by Dr. Gerald Oster, associate professor of polymer chemistry at the Polytechnic Institute of Brooklyn.

Dr. Oster's experiments show that in such reactions—designated diffusion-controlled because their rate is determined by the speed of diffusion of the reactants toward one another—glycerine increases the local viscosity of the reaction solution and hence influences the velocity of reaction. Other thickening agents such as gelatin, polyvinyl alcohol and polyacrylamide increase only the macroscopic viscosity of the solution appreciably, and have no effect on reaction rate. (Macroscopic viscosity refers to the viscosity of the entire solution; local or true viscosity, to the viscosity of the medium immediately surrounding the molecules in solution.)

This unique effect of glycerine has been studied quantitatively in four reactions. Results show that increasing the glycerine content of the media markedly alters the rate of clotting of blood, the rate of polymerization of vinyl compounds, the fluorescence of diphenyl methane dyes and the rate of photo-bleaching of dyes. Dr. Oster considers the effect on vinyl polymerization of most practical significance since both the rate of reaction and the molecular weight of the resultant polymer are enormously increased by the mere introduction of glycerine. In this case, the increase in viscosity caused by glycerine decreases the rate of the termination steps in the polymerization; hence, polymerization continues and high molecular weight polymers are formed rapidly.

### "Hot-Atom" Chemistry

Radiochemistry is a comparatively new field of science consisting of the application of chemical techniques to solving the problems of nuclear physics and, second, the application of nuclear physics to solving the problems of chemistry. According to Dr. Willard F. Libby, a Commissioner of the AEC, one of the most intriguing by-paths of this new field concerns what is called "hot-atom" chemistry.

In hot-atom chemistry the radioactive decay of an atom within a given molecule is used to synthesize new molecular species. Although the new technique is being investigated in many universities and research establishments here and abroad, it is not possible now to foresee any practical or economic advantage in producing new chemicals with the process. But the technique does provide yet another tool for research into the forces which hold atoms together within a molecule. These forces, of course, are much weaker than those within the nucleus of any particular atom.

Still another aspect of radiochemistry

is the use of nuclear radiation to induce chemical reactions. The practical applications of this new technique may become evident shortly: for example, a number of oil companies are using gamma radiation to induce chemical reactions under conditions heretofore not possible. The aim is to improve the properties of gasolines and lubricating oils. The polymerization of plastics under nuclear radiation is also being studied. Irradiated polyethylene with improved properties has already been placed on the market.

### The Latent Image

A new approach to probing secrets of the latent image—the unseen picture that exists on photographic film after the shutter clicks and before development—has been launched by Eastman Kodak Company. The new method involves supplying simultaneous pulses of light and electricity to a silver halide crystal. Such crystals are part of the light-sensitive coating on some photographic films.

The discharge of electricity is at the rate of 1000 times a second and gives 5000 volts across the crystal. Light is supplied from a pressure mercury arc. The extreme brevity of the exposure and voltage pulses have enabled photographic scientists to study the motion of electrons in the halide crystal for the first time.

One important feature of the experiments so far is that latent image formation follows the movement of electrons. This was indicated by displacement of the image to one side of a large crystal when the electrical field drew electrons in that direction. The new knowledge of the latent image is expected to aid in work on better photographic emulsions and in research on specialized photographic materials and equipment.

### X-Ray Study of Metal Stress

Basic studies of metal fatigue and corrosion may be aided by some new work done on the distribution of stresses between crystals in a metal. Using X-ray diffraction techniques, NBS researchers studied changes in the lattice spacing of crystals both under load and after release from load.

It was found that the magnitude and direction of the principal stresses can be computed for a certain loading condition in this way even though the elastic limit has been exceeded. The investigations have also led to a new explanation of the balancing of residual strains. These results should increase the practical utility of stress measurement by X-ray diffraction.

Previous work at the Bureau and elsewhere has shown that there is a certain range of applied stress over which the crystal lattice behaves elastically; beyond this point the strain as measured by X-rays remains nearly constant although the metal continues to deform. Also, when the load is released, a residual strain is left, oppo-

site in sign to that under load. The present investigation sought to answer such questions as the following: (1) Is the elastic limit the same in all directions relative to the applied stress? (2) What is the nature of the residual strain observed after plastic deformation and how is the stress causing this strain balanced?

To provide the necessary data, an investigation of lattice strain in 17 directions in a low-alloy steel was conducted by H. C. Vacher, R. Liss, and R. W. Mebs of the Bureau's mechanical metallurgy lab. Measurements were made both under load and after release of load, the successive loads being of increasing magnitude. The specimen was essentially a hollow cylinder— $\frac{7}{8}$ " OD x 2" long, and  $\frac{1}{8}$ " in wall thickness—with portions machined away so as to leave a reduced section consisting of three symmetrically spaced legs  $\frac{3}{8}$ " long and triangular in cross-section. This type of design was adopted so that the specimen would be stable in compression and wouldn't need big loads for high stresses.

Other investigators had previously noted the development after plastic deformation of residual stresses opposite in sign to the applied stress, and various explanations have been offered to account for the necessary balancing stress. One theory is that the stresses are due to the anisotropic behavior of individual crystals and are balanced by opposite stresses in adjacent crystals of different orientation. The Bureau's results do not support this theory, as a wide range of orientations were studied and all of the residual strains appeared to arise from a single stress system.

As the experimental results do not agree with any of the current theories, the NBS investigators propose the following explanation for the balancing of the observed residual strains; it is suggested that this balancing is supplied by stresses in material in which the crystal lattice is so distorted that it does not scatter X-rays coherently. Such material might be found at grain boundaries or in slip bands.

### Cobalt Information Center

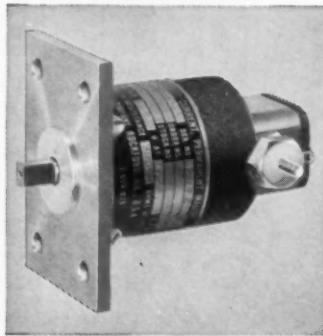
A Cobalt Information Center has been established at Battelle Institute, Columbus, Ohio. Its purpose is to encourage cobalt research and to provide technical and economic information for users throughout industry. Data on technological advances will be gathered and organized at the Center, which is being supported by major cobalt producers.

Currently, about 55 percent of the cobalt consumed in the United States is produced in North America. One-third of U.S. consumption goes into high-temperature alloys and another 28 percent is used in magnets. At present levels of world consumption, it is estimated that known cobalt reserves will last about 40 years—probably longer than zinc, lead or tin, and as long as nickel—at present production rates.



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## SERENDIPICS

### From Erector Set to Engineering Laboratory

Two years ago, GE engineer Sterling Newberry attracted much attention as one of the developers of the X-ray microscope. Now Newberry is making news again, as the result of an Erector set stimulating sheer Yankee ingenuity.

While Newberry watched two of his four small sons playing with an Erector set, he suddenly saw how to solve a troublesome problem in the company's General Engineering laboratory. When the youngsters converted an Erector suspension bridge into an oil derrick merely by shifting a few toy girders, a way to save hundreds of hours in time-consuming laboratory experiments flashed into Newberry's mind.

Using the Erector set idea, he built a gadget-loaded test bench in the lab, where the bench accessories could be hooked up in many different combinations. Called an electron-optical bench, this lab version of the Erector set has become a valuable engineering tool for studying the complex behavior of electron and ion beams. Thanks to the new "adult" toy, tests that formerly required several days of preparation can now be set up in a few hours.

### For the Person Who "Has Everything"

Perplexed by what to get Uncle Muchbucks for his birthday? You could settle on something as small as a solid gold toothpick in an alligator case, or as large as a mink-upholstered Mark II replete with air-conditioning. But if these somehow don't ring a bell, the Norma Pencil Corp. of New York may have a more practical answer to your dilemma.

It's a cinch that Uncle Muchbucks must sign his dividend checks, and you can make this an even more delightful chore by presenting him with a Norma "Multikolor" platinum mechanical pencil: price \$500. If you balk at this, you might settle on the shabbier palladium model at \$250.

Norma proudly boasts that these are the most expensive practical writing instruments ever made (we thought Paper-Mate was doing fine with a \$50, diamond-studded version of its ballpoint pen). But if anybody thinks this is the pen-ultimate, they just don't know American merchandising methods. There must be a profitable market, however small, for a \$1000 writing device, and the enterprising pen and pencil people are sure to find it.

### For Want of a Hair

We have at last found proof that research is not as staid and humdrum as some would have you think. While scientists and engineers do work hard and experiment endlessly (one scientist we know of ran 167,000 tests on a bacteria found on his thumbnail to determine its felicity with a bacteria of the opposite sex), research does occasionally furnish entertaining highlights.

At Evans Research & Development Corporation in New York, for example, an eminently serious research program resulted in a contest to see which scientist could grow the biggest beard. Evans, it seems, urgently needed samples of human beard hair. Since such a product is not commercially available, they turned to members of the staff. The result was a luxuriant growth of bristles on the faces of several staff members who responded with scientific verve.

Our intelligence informs us that a Mr. William D. Davis won the honors, with a straight, black beard that grew to well over an inch in two months.

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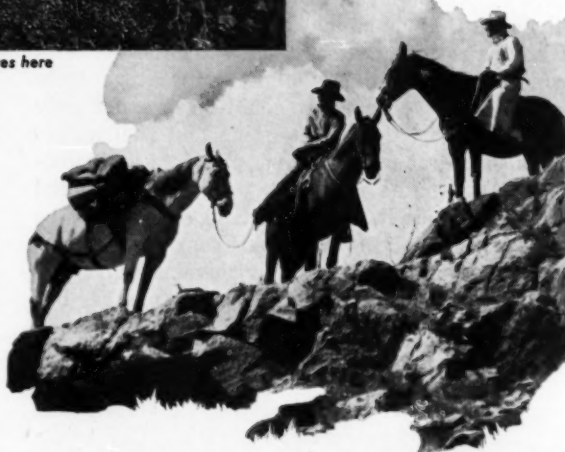
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### SYMPOSIUM REPORT

The push is on for high temperatures: how to generate them; how to measure, control and contain them; how to use them. For researchers and engineers now agree that ultra-high temperatures can be a technical cornucopia of new products and processes perhaps beyond our current capacity to imagine.



## HIGH TEMPERATURE—Tool for the Future

Aeronauticists, hard at work in their attempts to reach the moon, have no doubt that ultimately they will get there. However, how soon they do so may well depend upon their colleagues who are reaching for the sun—that is, the temperatures contained therein. For high temperature technology appears to be the key that could release not only the materials needed by airframe, engine and fuel manufacturers but also a host of other new products and processes for use on Earth. As Kurt Schuler of the National Bureau of Standards put it, "Flames could conceivably be our 'chemical factories' of the future". From here on emphasis will be placed on developing new chemicals and new materials not by putting atoms and molecules together but by combining ions and free radicals at temperatures comparable to those existing in the sun.

Last June 25, 26 and 27 almost 700 chemists, physicists and engineers from nearly 300 industrial, university and government organizations gathered at Berkeley, California, to swap new-found information and to fling questions at each other in this field. Perhaps the most significant aspect of efforts to reach sun-temperatures lies in the fact that it is truly an "Operation Bootstrap". The attainment of ultra-high temperatures under stable, steady-state conditions is limited by materials to contain and to generate them; and this in turn is limited by insufficient knowledge of the properties of materials at high temperature levels. One new material—developed either by a sledgehammer approach or a neat, speculative, conceptual venture into the sun's interior—could break the cycle and permit the use of higher temperatures, which would permit the operation of processes resulting in still better materials for still higher temperatures. Then could come the big pay-off in

terms of new corporate ventures in the making of commercial and consumer products.

### IMAGES OF VERY HIGH TEMPERATURE SOURCES

The three-day Symposium was quite logically divided into three areas: methods for reaching high temperatures, materials for containing high temperatures, and processes occurring at high temperatures. Joseph Farber, Manager of GE's Real Gas Operation, opened the first day's panel with a question: "If one has a high-temperature source, why then go to all the bother of trying to make an image of it instead of just using the source?" The answer is that it is easier to work with the electro-magnetic radiation of the source than in its environment.

Farber explained that the study of oxides or oxidation at high temperatures in the reducing atmosphere generally available in high-temperature flames and induction furnaces is difficult. Likewise the presence of magnetic and electric fields limits the areas of meaningful studies in arcs. And high-temperature sources often have large temperature gradients in them which increase experimental difficulties. Radiation emitted by the source is both the method of escape from the source-yielding problems and the beginning of the problems for the utilization of images as a technique for the attainment of and studies of phenomena at very high temperatures.

Problems center around image sources, their temperature, geometry, and spectral and geometric emissivity; the focusing system with its reflectivities and optical characteristics; and finally the receiver of the radiation, its geometry, spectral absorbance, and its conduction, convection and radiation losses.

### Sources

The chief and practically the only source used has been the sun. There are some obvious reasons for this. It is generally available and has an equivalent black-body temperature of around 6000K. The sun, however, limits the size of images. Thus the 34-inch focal length of the 120-inch Convair-Conn solar furnace has an image diameter (at the vertex) of 0.34 inch because of the small angle subtended by the source of 32 minutes (0.00932 radians).

Turning to earthly sources, Farber covered problems associated with flames. All the high-temperature flame constituents are, at most, diatomic species and at the temperatures of interest not too readily ionized. For imaging it is necessary to have a black body as near to the flame as possible. The atomic species can contribute only in narrow bands to radiation emitted and is therefore of little importance. Other constituents are diatomic species and usually contribute in small regions of the spectrum. At high enough temperatures, some of the free-bound emissions can become dominating as is the case of oxygen atoms and at 10,000K can contribute very large quantities to its ionization potential.

Normal constituents of flames do not readily yield their high-temperature radiation. Farber feels that it is desirable to add small radiating impurities to these high-temperature flames, preferably of a polyatomic molecular nature (stable at very high temperatures) and into a flame of long path length with the requirement that the impurity not change the temperature of the flame appreciably.

Although temperatures have been reported of the order of 16,000K for high-current arcs, most of the light radiation has come from the vaporizing material at the anode. These temperatures are around 5000K for carbon and can go as high as 8000K for tungsten. For low-current arcs, the addition of salts increase arc luminosity which also decreases the arc temperature. Here again it would be valuable to be able to introduce stable polyatomic compounds to increase the emissivity of the arc column.

Radiation from a source must reach the collecting and circulating system. Usually only about 50 percent of the sun's light incident to the atmosphere is available. In some instances up to 90 percent has gotten through. Likewise in

arcs and flames the environment must be transparent to most of the radiation. Low-temperature air is transparent from 1900 angstrom units to all higher wavelengths, (assuming no  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{O}_3$  present). Pure air is therefore an excellent environment at low temperatures.

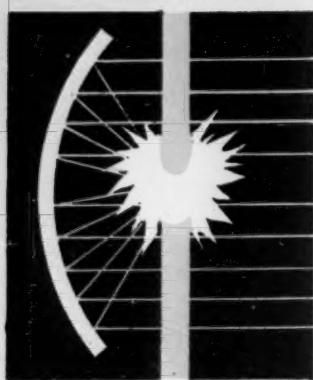
At slightly elevated temperatures, to around 2000K, the formation of  $\text{NO}_2$  can absorb radiation over a wide range and thus form a temperature shield. If the cool layer near the high-temperature source is kept relatively thin then only small losses will be present because of  $\text{NO}_2$ .

Effective geometry of the source is a function not only of the source configuration but also transparency and temperature gradients. The sun behaves nearly as a disc because of its highly transparent outside layers. Therefore, all relatively transparent spheres act almost as discs; cylinders act as near plates and conical shapes appear as triangular pieces. For imaging the most efficient shapes are discs and spheres which, of course, would not always be available.

### Receivers

Farber covered quantitatively and qualitatively—problems of transferring emitted radiation into suitable images at desired locations. Different types of reflectors, reflection surfaces, emissivity of receiver surfaces and their effectiveness control the end result. However, it is the receiver of the radiated energy that makes or breaks a particular system ultimately; it is also the place where a number of optical tricks can relieve the problems of the source. Farber reported only three geometries investigated to date: the disc, the hemisphere which produces slightly lower results, and the "hole".

According to Farber, the spectral absorbance of the receivers may make it possible to utilize sources which emit in selected regions if the receiver absorbs in these regions and emits in more red regions much less (i.e., has an emissivity much lower in the longer wavelength region than the region of source emission). If the flux is sufficiently large from the source and absorbed appreciably by the receiver to overcome conduction and convection losses, then the receiver can approach the temperature of the source.



**THE CARBON ARC  
IMAGE FURNACE**

T. P. Davis of the Atomic Energy Flash Burn Section, University of Rochester, concentrated on the arc image furnace which provides many unique advantages: ease of control, stability, reproducibility, and moderate size and cost. While a certain amount of his discussion was applicable to high intensity arc discharges in general, he specifically treated only the high current carbon arc.

Utilizing this source in an imaging-type furnace involves the design of a suitable optical system which will gather as much radiation as possible and concentrate it in a useful exposure plane. Many applications call for control of irradiance (radiant energy flux per unit area) and time of exposure. Finally, the radiation, to be useful, must be absorbed *within* the irradiated sample. Although the last point is not strictly within the purview of arc-imaging methods, per se, it is nevertheless a distinctly important problem. While high absorptance in the case of solid samples may be achieved by surface blackening or cavity-type sample geometry, considerable effort may be required to secure adequate absorptance in gas phase samples. Solutions to this problem are generally unique to each application.

#### **Design of Optical Systems**

The simplest optical system consists of no optics at all; merely a source and, in close, the sample to be irradiated. While such a system eliminates reflection and absorption losses in optical elements, the small area of the source requires the sample to be placed very close to the positive crater if high irradiance is desired. When small sample size makes such placement possible, Davis cautioned that the advantages of this system should not be overlooked. Extending this method to secure smaller and smaller separation between source and sample leads to such methods as the Sheer-Korman Process where the material to be studied is incorporated in the positive carbon itself. Here, however, the material may be heated not only in the positive crater region, but also in the higher temperature contracted-arc-stream region, and temperatures may be achieved considerably in excess of these possible with arc-imaging methods.

The second method, the one most commonly used, involves reflection optics with two different systems. In the first, the positive carbon crater is placed at the focal point of a paraboloidal mirror and the approximately parallel rays from this reflector are brought to a focus by a second, identical parabolic mirror. One advantage is the immediate applicability of standard service searchlights. Thus, one of the units developed and used by the Material Laboratory of the New York Naval Shipyard employs two naval 24-inch searchlights directly facing one another, with the major modification being the replacement, in one lamp, of the

arc mechanism by a sample-holding device. A second advantage is that the radiation between the two reflectors is approximately parallel; therefore, asymmetric diaphragms or other limiting stops placed in this region will not produce asymmetry in the image. Further, controlling elements introduced in this region are subjected to relatively low irradiance, which can greatly ease the problems of adequate heat dissipation from such elements.

An important characteristic of this system is that since the two mirrors are of identical focal length, unity magnification is obtained with consequent high irradiance at the exposure area. In the source developed by the Thermal Branch of the U.S. Naval Radiological Defense Laboratory, the peak irradiance is 90 cal per sq cm per sec, or almost 380 watts per sq cm. This source employs a 16mm positive carbon operated at a current density of about 85amp per sq cm; the two parabolic mirrors are aluminized stellite of 36-inch diameter and about 14-inch focal length. With its attendant controlling and monitoring equipment, this is a good example of the high state of development of this type of system.

While the unity magnification of the "double parabolic" system does yield high irradiance, it has the disadvantage of restricting the exposure area to a rather small size. Thus, for the NRDL source, the irradiance drops to 90 percent of the maximum value at a radial distance of 0.3cm from the optic axis. Also the large entrance angle of the mirrors, about 120 degrees, means that radiation will strike the sample at angles of incidence up to 60 degrees, which can be disadvantageous in those cases where the sample exhibits increasing reflectance with increasing angle of incidence. Further, the two reflecting surfaces give an unavoidable loss in efficiency as does the screening effect of the sample and sample holder which must be mounted between the two mirrors.

Certain of these disadvantages are avoided in the second type of reflection system. Here the positive crater is placed at the first focus of an ellipsoidal mirror, and an enlarged image of the source is then obtained at the second focus of the mirror, the degree of magnification depending upon the ratio of focal lengths. In the source developed by the Flash Burn Section of the University of Rochester Atomic Energy Project, the reflector used is first surfaced aluminized glass of 24-inch diameter, with first and second focal lengths of about 11 inches and 52 inches respectively. With this system, not only are the losses from a second reflecting surface and sample screening eliminated, but also the larger image permits a greater area of fairly uniform exposure. Further, while the angle subtended by the mirror at the first focal point is again about 120 degrees, the angle of incidence of the most extreme ray at the exposure plane is only about 16 degrees, with the reflector mentioned above.

The principal disadvantage of this system, according to Davis, is the reduction in maximum obtainable irradiance caused by the magnification of the source. This reduction need not be as great as the square of the lateral magnification, as might be first suspected, since a consideration of a simple imaging system utilizing a source of finite size indicates that there will be a position on the optic axis, within the point of best focus, where the irradiance will be a maximum. Selection of this point as the exposure plane entails a loss in useful exposure area, so a choice must be made between maximum irradiance and exposure area. In the University of Rochester source the exposure plane has been selected at this position of maximum on-axis irradi-

ance, and the exposure area then limited to the central circular area of 1 sq cm (1.1 cm in diameter) within which the spatial variation of irradiance is only about 12 percent; over this area the average irradiance is 34 cal per sq cm per second or slightly over 140 watts per sq cm.

The third system discussed by Davis employs refraction optics. An outstanding advantage of this system is no reversal of direction of the rays, as with a reflection system; not only is the obscuration of the sample eliminated but also that due to the lamp mechanism itself. Another advantage is that the magnification can be varied with a given set of elements, and that one can choose between high irradiance and large exposure area by suitable placement of the exposure plane. In spite of these advantages, this system is not as widely used as the reflection method because of the difficulty of obtaining heat resistant lenses of sufficiently low  $f$  number.

One of the large sources utilizing refraction optics is that developed by the Naval Radiological Defense Laboratory group. This unit, termed the Mitchell Source, employs a modified Mitchell Process Projector, burning a 16mm positive carbon at current densities up to about 110 amp per sq cm. The optical system consists of a pair of condenser lenses which form a primary image of the positive crater; the image is then used as the source for a second pair of lenses, the relay lenses. The exposure plane is located well inside the second focal point of the relay lens system at a position such that each point of the primary image covers every point in the exposure area. This source provides a peak irradiance of 30 cal per sq cm with the maximum image size given as 3.5 cm (1.4 in) diameter, which is considerably above the other units Davis described. Another advantage of this particular condenser-relay system is that any asymmetric diaphragming at the prime focus of the condenser will not yield asymmetry in the energy distribution in the exposure plane. This is similar to the case with the double parabolic reflection system, but here the beam cross-section is much smaller; thus formation of various time-irradiance pulses is quite possible by interposition of rotating disk cams at the prime focus plane.

#### LARGE-AREA HIGH-TEMPERATURE SOURCES

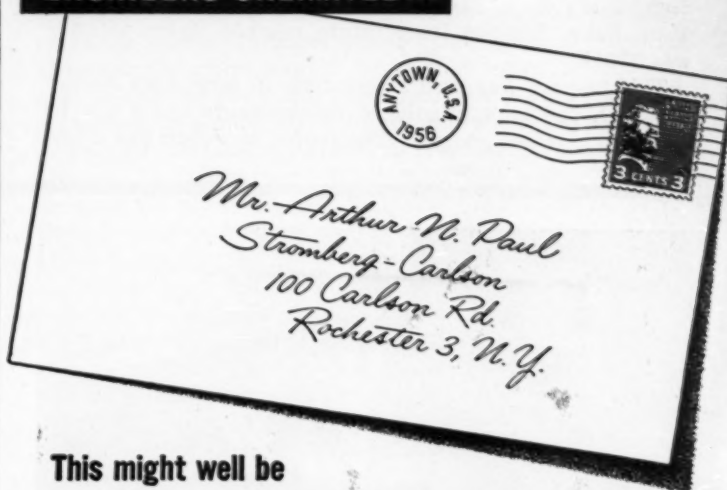
Joseph M. McGreevy of the N. Y. Naval Shipyard has been working with sources of intense thermal radiation capable of irradiating areas up to one foot square. The Naval Material Laboratory has been engaged for the last five years in experimental studies on the effects of thermal radiation from atomic weapons on materials of interest to the military services. Material of main interest to them are fabrics, constructional materials and materials that can be substituted for human skin in the study of sub-fabric burns.

After several failures with open radiant panel designs, McGreevy turned to an enclosed furnace. Advantages are:

- Power emitted by a large-area irradiator can be tremendous, and, having a means for thermal storage, makes it possible for the input power to be moderate.
- Enclosure interior is the emitter and thus provides a higher effective emissivity.
- It is more feasible to place a specimen to be irradiated close to a furnace port than to a radiant panel.

For these reasons, the Material Laboratory engaged the Kuhlman Electric Company of Bay City, Michigan, to build a graphite-resistor furnace, essentially a box with an 11-inch by 13-inch opening, graphite-lined, with two hairpin-

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shaped graphite resistors. Each resistor operates at a maximum 36 volts and 3000amp. Power input is not kept constant during a run, being about 50 to 100kw at the beginning of a run, to heat the furnace, and then lowered to about 30kw. Highest temperature reached in the interior was 2700K.

This furnace was used successfully in large-area studies in which the high irradiance requirements could not be provided by other sources. The source, however, has a few

disadvantages: the high installation cost (\$13,000) because of the special transformer required, and rebuilding is necessary after every 25 hours of use.

NACA Langley Aeronautical Laboratory in Virginia has a radiant panel that appears to have promise for investigational work requiring irradiances of about 30 cal per sq cm/sec. Descriptions of this source are contained in two reports by Kotanchik and by Kotanchik and Ross of the Langley Laboratory.

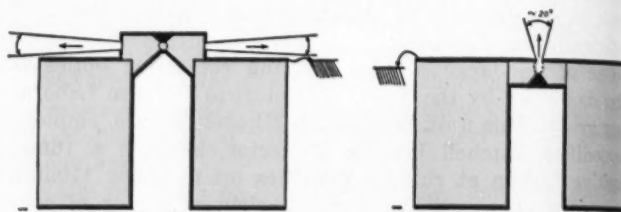


Photo at left shows Fischer's coaxial capacitor discharge system; schematic above illustrates the coaxial circuit.

### SHORT TIME, HIGH TEMP PULSES

Last March, Heinz Fischer of the Air Force Cambridge Research Center reported reaching gas temperatures over 250,000K in helium at gas pressures around 30 atmospheres, using a coaxial capacitor discharge. The technical problem in such bursts is how to release maximum electrical energy into minimum volume in the least time possible. This raises the question of whether thermal equilibrium within the plasma can be accomplished within the pulse length (about 1 microsec) and whether the energy has a Boltzman distribution. For these reasons, Fischer has concerned himself with the definition of gas temperatures and their measurement.

Fischer's electrical circuit consists of a large toroidal capacitor ( $C = 2.75\text{mm/d}$ ) which surrounds the spark gap coaxially reducing the inductance ( $L$  about  $0.035\text{mmh}$ ) of the complete circuit to a minimum; the ratio  $C/L$ , called efficiency factor, was made a maximum. Increase of  $C/L$  leads to increased gas temperature, proven experimentally. Instability of the discharge was a limiting factor and still is. The spark channel is unrestricted (no squeeze); spark currents are in the order of 10 to 50kiloamp with current densities approximately 1 million amp per sq cm; pulse length approximately 1 microsec; breakdown voltages under 7kv.

Fischer determined gas temperature from the absolute radiation density (approximately 150 million candles per sq cm) assuming black-body radiation. The true gas temperature is considerably larger because of the transparency of helium—the spectrum of which was found continuous within the visible spectral range. Approaching thermal equilibrium within the plasma may be assumed because of the high gas pressure and the large amount of ionization.

The Russian scientist, Igor Kurchatov, in a recent lecture disclosed an estimated gas temperature of close to one million Kelvin in deuterium, also by coaxial capacitor discharge. The capacitor energy as well as time constant of

his circuit were considerably larger. However, the current density was comparable to that of Fischer's. Definitely different, however, were the low gas pressure (1—750mm Hg) and the restriction of the spark channel, apparently by means of tubing, which is possible at low pressure.

Reduced pressure in combination with the "squeeze" allows smaller channel volume if expressed in number of heated molecules. Thus larger gas temperatures can be obtained in principle at smaller gas pressure provided that the same amount of energy can be transmitted into the channel. Fischer raised serious doubt, as to whether thermal equilibrium is reached because of the reduced number of collisions. The restricting walls, on the other hand, favor the excitation of magnetic hydrodynamic oscillations within the plasma, causing directed velocities. In fact, Fischer stated that the fusion processes reported by Kurchatov could be proven *not* to be thermal.

### Pinch Effect

At low pressure the expansion of the channel may be counter-balanced by the self-magnetic field of the channel, which with increasing current density may lead to pinch. This effect has been used in the electrodeless ring discharge to produce low pressure plasma with high ion density.

For the apparatus used by R. E. Vollrath of USC, a toroidal tube, the discharge is initiated by an outside capacitor discharge (69mmfd, 7000v) connected to the toroid by means of inductive coupling. Constriction of the channel (about 1 sq cm diameter) was observed with 6000amp and a gas pressure of  $0.04\mu\text{m Hg}$ ; pulse length is about 10 microsec.

Bostick, Levine, Zimmerman and Combes from Tufts use a similar setup. Their currents are somewhat larger, 8000—15000amp, with comparable channel diameters (about 1 sq cm), pulse length about 10 microsec and gas pressures around 1 mm Hg. Gas temperatures of about 250,000K were estimated from the widths of spectral lines.

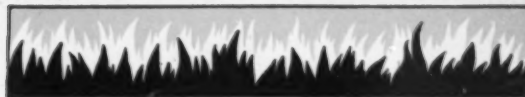
## HIGH TEMPERATURES—ELECTRICAL METHODS

Limitations on the means of reaching high temperatures are set by materials problems. In turn, availability of these high-temperature materials depends on both high-temperature processes and on the equipment available for reaching the high temperatures. This interdependence among methods, materials and processes was emphasized by H. G. MacPherson of National Carbon Research Laboratories.

For continuous temperatures not to exceed about 1100C, MacPherson reports "Nichrome" alloy to be the best of the available resistance materials. For operation up to 1500C the standard resistance element for lab use is now the "globar" or silicon carbide rod. Above 1500C, platinum, and platinum alloys have frequently been used, but they seem to have an upper limit of about 1500C for continuous use. The resistor elements named so far can all be used in air, considerably increasing their versatility. MacPherson knows of no metal system that can be used continuously above 1500C in air without some type of special coating. Molybdenum, for example, can be coated with molybdenum disilicide and, in this case, has been reported to give 100 hours of operation at temperatures as high as 2000C.

Resistor furnaces suitable for operation in air to temperatures of at least 2050C can be made from a refractory oxide resistor. Since these oxides are very poor electrical conductors at low temperatures, a supplementary source of heat (a platinum resistor furnace surrounding the oxide resistor furnace) brings them up to temperature. It is the best furnace for reaching 2000C in an oxidizing system.

For use in reducing or neutral atmospheres, or for use in vacuum in the very-high-temperature region, common resistor materials molybdenum, tantalum, tungsten and graphite are in use. Because of its greater ductility and ease of handling, molybdenum is preferred in the 1500—2000C range. For extended use above 2000C tungsten must be used because molybdenum becomes too volatile.

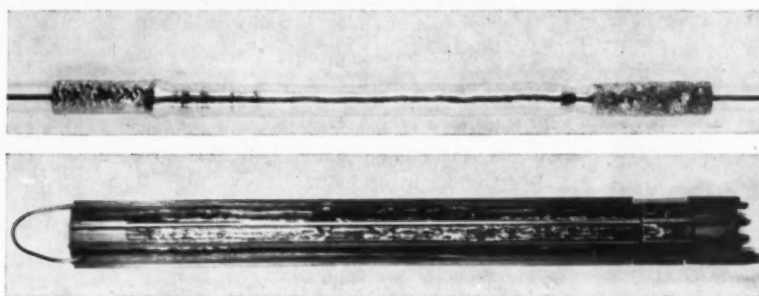


Graphite is the most common resistor material for horizontal or vertical furnaces above 1500C. Vertical furnaces are generally more adapted for vacuum operation and can also be used more readily with radiation shields for heat insulation. In some designs a graphite tube cut in the form of a spiral increases the electrical resistance of the heating element. In others they are cut in various ways, either to increase the electrical path and thus the resistance, or to make it possible for both electrical connections to come out of the bottom of the furnace.

Another good design for such a vertical furnace is to have the graphite resistor made up of a squirrel cage of small diameter graphite tubes. MacPherson recommends this type of furnace because it optimizes a number of features, including the ease of replacing individual resistor elements should they burn out. Granular resistance furnaces depend on contact resistance between the particles of a solid higher than the bulk resistance of the material itself. Although granular resistor furnaces are in large-scale commercial use, MacPherson feels they deserve more attention. Furnaces devised by Dr. E. G. Acheson for the commercial production of silicon carbide and of graphite use granular carbon as the furnace resistor element. Some lab furnaces use either granular carbon or a mixture of carbon and silicon carbide as a resistor.

An interesting use of a granular carbon resistor employs the high resistance of the granular carbon to provide an extra source of heat at the ends of a furnace of about cubic dimension. Combined with the use of thin carbon slabs for heating elements at the sides of the furnace, it provides a nearly uniform generation of heat on all sides. Suspending the lower end of a graphite spiral into graphite powder provides the bottom current connection and generates extra heat near the bottom.

*continued on page 34*



### LEVITATION MELTING OF METALS

Levitation melting of metals may solve the problem of melting metals that react with nearly all crucible materials. Left: levitated molten aluminum suspended in space as it is melted by a 10,000 cycle, 600amp induction coil. Top: floating zone levitation; Below: cage zone levitation.

WOLFGANG FINKELNBURG

Head of Research, Siemens-Schuckertwerke AG, Germany

## BEHAVIOR OF MATTER AT HIGH TEMPERATURES

Technical use of matter at high temperatures has generally been limited to below 4000K. Now, the trend is to study the behavior of matter between this limit and the highest temperature obtainable—some 50,000K. Here's an analysis of the problems confronting engineers, metallurgists and process chemists who will surely and quickly follow the physicist in this new domain.

Four conditions must be met before the engineer can apply high temperatures technically:

- he must produce such high temperatures
- he must measure them reliably
- he must possess a sound knowledge of the behavior of matter at these temperatures, of their laws and associated material constants
- he must finally master the art of handling matter at these high temperatures, including their containment in solid materials.

Considerable progress has been made in the past decade in the first three points. However the engineer will have to modify his scientific outlook because the laws of atomic physics play such an important part in the understanding of the behavior of matter at high temperatures. We are still at the beginning in technological control of matter at high temperatures. But in this field too, experiments provide significant clues. For instance, a water-cooled copper plate may remain in thermal contact with a gas at 20,000K for some time without melting.

### Changes in a Gas at High Temperatures

Consider the change of the behavior of a gas such as nitrogen by increasing its temperature. Up to about 2000K an increase in the random thermal vibrations of the gas molecules occurs almost exclusively. At 7000K the state of the gas has already changed markedly. About one-third of the original  $N_2$  molecules are split into N atoms by thermal dissociation, and the intense radiation of the gas shows that the electron shells of the atoms and molecules are excited

thermally. The gas still remains a fairly good electrical insulator; only about one percent of the atoms or molecules have lost one of their outer electrons due to the high temperature. At 12,000K there are practically no more molecules because of their complete thermal dissociation. By this time one-seventh of the original nitrogen atoms have lost one electron by thermal ionization. The existence of free electrons and positive ions brings about a considerable electrical conductivity. At about 20,000K the double ionization sets in, causing formation of  $N^{++}$ . At 30,000K, 60 percent of the gas particles already are free electrons. The remaining particles are free electrons. The remaining particles are divided in even parts of singly and doubly ionized nitrogen atoms, the neutral nitrogen atoms having practically disappeared. The temperature rise produces a fundamental change in the composition and properties of the original gas, justifying the introduction of the new concept of *thermal plasma as a fourth state of matter*.

Consider these radical changes: The particle density of the gas has fallen to one percent of the original value, at the same pressure, as the absolute temperature exceeds the original temperature 100-fold. Only about one-third of the new gas particles are heavy particles having approximately the same mass as the nitrogen atoms. The rest of the gas consists of nearly mass-less electrons. Mean molecular weight of the gas has consequently fallen from about 28 to barely 5. Its actual density measured in grams per cc has fallen to about two per 1000.

At all temperatures above 6000K a large num-

ber of chemically active nitrogen atoms or ions are present, comparable to atomic hydrogen now being used industrially. Matter at such high temperatures radiates intensely, a fact that is now used in modern thermal light sources such as mercury arcs, high-pressure xenon arcs, and other arc lamps. While the initial nitrogen gas is an excellent electrical insulator, the thermal plasma is an excellent electric conductor. Its specific resistance is only twice that of the metal form of mercury.

The highest temperature that we can produce presently in nitrogen is about 35,000K. At still higher temperatures the ionization of all the atoms proceeds step by step until finally, between 10 and 100 million degrees, the gas consists of a mixture of bare nuclei and free electrons. This is the state of matter in the innermost regions of our hottest fixed stars. In this temperature range, thermonuclear reactions occur on a large scale. Such changes, however, are outside the scope of this article.

#### Production of High Temperatures

Chemical reactions such as flames do not produce temperatures much beyond 5000K. Older computations that claimed higher values neglected the energy loss due to thermal dissociation. Production of high temperatures of very short duration by mechanical compression of gases in the front of detonation waves and, in particular, by their collision leads to values estimated between 10,000 and 15,000K.

Extremely high temperatures, supposedly up to 1,000,000K, can be produced for very short time periods by extremely powerful capacitor discharges. Their accurate measurement, however, is difficult. The short duration of these phenomena not only makes their investigation difficult, but also raises considerable doubt as to whether true thermal equilibrium exists between all particles of the plasma. The short-time, high-temperature phenomena include the atom bomb; according to reports, maximum temperatures of a few million degrees have been obtained. But we do not like to consider them practical experimental devices of the physicist.

For the production and investigation of matter at high temperatures in stationary equilibrium, only the electric arcs of high current density remain. Examples: the high-current carbon arc with an axial temperature reaching 12,000K, the 500-amp arc between well-cooled metal electrodes in argon and nitrogen with a maximum temperature of 30,000K, and finally the very special arcs developed by Gerdien and Lotz. In the inner portions of water-cooled diaphragms, these arcs produce current densities reaching 30,000amp per sq cm, and a maximum temperature somewhat in excess of 50,000K. In all these arcs stationary equilibrium is maintained, since the input of electrical energy compensates for the losses due to radial heat conduction and radiation. However, it is also possi-

ble to produce and investigate extreme temperature plasmas to which no energy is added and in which, consequently, no electrical field exists. The anodic flame of a high-current carbon arc is an example of such a thermal plasma in which nearly all solids can be vaporized and investigated at temperatures between 5000 and 8000K. Temperatures up to 13,000K have been measured in the water-vapor plasma-stream protruding from a Gerdien arc. And a supersonic plasma jet of 8000K was produced by Peters in our laboratory by expanding the plasma of a water vapor arc burning under 50 atmospheres pressure through a Laval nozzle drilled through the axis of the anode.

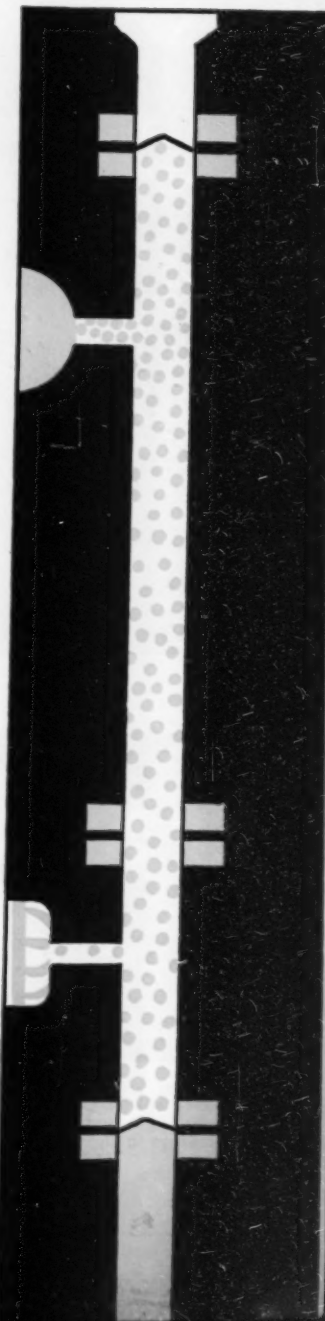
#### Temperature Measurement

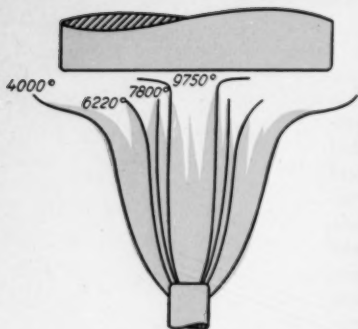
Temperature data have been freely mentioned here without specifying methods for measuring such temperatures. Disregarding the not very exact method of obtaining temperature values from the gas density measure by x-ray absorption in the arcs, all measurements or temperatures in the thermal plasma involve atomic methods based on conclusions about the temperature from measurements of the radiation of molecules, atoms, ions and electrons. Application of such an "atomic thermometer" is possible only for researchers with sufficient knowledge of atomic theory to permit calculation of the radiation as a function of the temperature. Only a few examples may be cited.

For the outermost reddish envelope of the carbon-arc stream, observation of the spectrum shows that the radiation is emitted by CaO molecules. Calculations with known molecular data indicate that these molecules have a sharp maximum in their radiation at 4000K and therefore radiate strongly at this temperature only. Hence this is the temperature of the reddish-brown envelope of the carbon arc. Radiation due to argon ions reaches its maximum at 28,000K; a complicated evaluation of the spectroscopic studies of the 500-amp argon arc that this temperature exists somewhat outside of the arc's axis. The temperature of the hottest region in the arc axis itself is, therefore, still a little higher than 28,000K.

Temperature of pure substances (not mixtures) in the plasma state can also be calculated on the basis of the spectroscopic measurement of the degree of ionization; that is, the portion of the atoms which have already lost one electron. Similarly, and under the same circumstances, the temperature can be calculated on the basis of the intensity of the continuous radiation emitted by free electrons according to a theory developed by Unsöld.

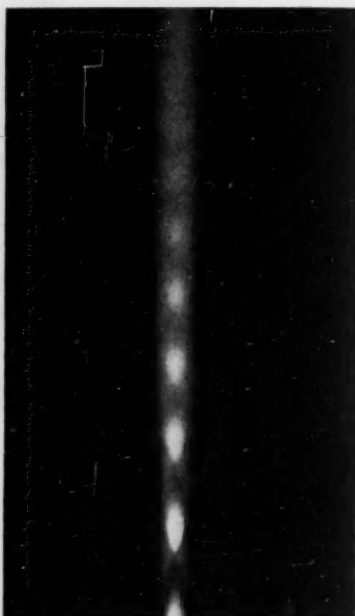
Thus, the physicist today can measure temperatures up to 50,000K with the same accuracy as the engineer measures the temperature of liquid steel in a furnace. However, such measurements are easy and dependable only in the case of pure substances and in a few other





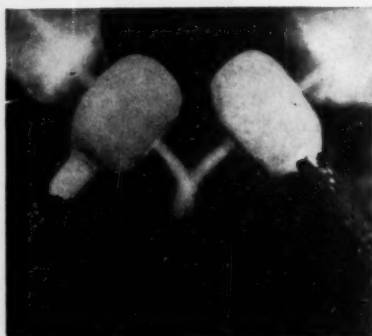
Temperatures in the 200amp high-current carbon arc stream measured by Maecker (temperature in K).

High-current carbon arc of 200amp with axial temperature ranging from 10,000 to 12,000K.

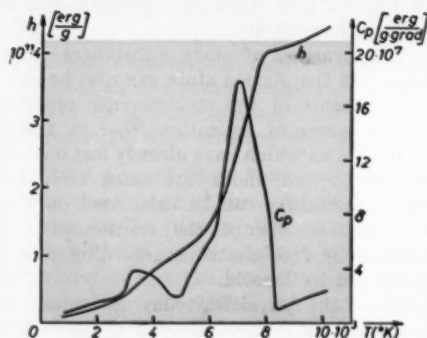


Supersonic water-vapor plasma jet of 8000K and  $6.5 \times 10^5$  cm per sec velocity, after Peters.

High-current Beck arc (200 amperes). The long anode flame protruding from the 11 mm-positive carbon (left side) is caused by evaporation of the positive core material heated by temperatures up to 8000K.



Gerdien arc constricted by two orifices cooled by a water film between their inner surface and the arc. Temperature in the orifices up to 50,000K.



Enthalpy  $h$  and specific heat  $c_p$  of air as a function of temperature up to 10,000K (unpublished, by Wienecke).

favorable cases; the development of more general and dependable methods still has a long way to go.

#### Properties of Matter at High Temperatures

A few further properties of matter at extreme temperatures may be mentioned to show how fundamentally different the behavior of a thermal plasma is from that of the original gas or material at lower temperatures. Specific heat and enthalpy of a plasma not only differs numerically from that of ordinary gas by orders of magnitude, but it also shows a non-monotonic change with temperature. Its cause lies again in atomic theory.

In those temperature ranges where an important change of the plasma composition takes place because of thermal dissociation or ionization, each increase in temperature requires a much greater amount of energy than in other temperature ranges. In these regions the curve for the specific heat shows steep maxima. For the same reason the thermal conductivity of the plasma of a gas differs radically from that of a gas at lower temperatures, a fact that is of great importance for future technical calculations. R. Wienecke (report not yet published) has investigated the behavior of suddenly disconnected high current carbon arcs using very-high speed photographic methods. Through these methods, photographs of the arc were obtained at the rate of nearly one million per second. By a complicated evaluation, Wienecke obtained the heat conductivity of the arc plasma of air with some carbon vapor as a function of the temperature. In line with the theory, his heat-conductivity curve shows a steep maximum in the range of the large change of the degree of dissociation with temperature. The conductivity at the maximum exceeds that of the gas at lower temperatures by a factor of 25. Similar maxima must be expected at still higher temperatures, in view of the different stages of ionization of the atoms. Reasons for the discrepancy from the theoretical lower curve are not yet known.

Finally, we might mention the electric conductivity of a high-temperature plasma caused predominantly by free electrons of the atoms and ions present with which the electrons collide and are hence impeded. Maecker and his collaborators have recently succeeded in obtaining reliable experimental values for the so-called effective cross-section of the atoms and ions using accurate measurements of electric arcs in various temperatures and pressure ranges. His results agree with the new theoretical work of Spitzer and form the basis for a dependable calculation of the electric conductivity of a high temperature plasma.

Thus high-temperature research is extending approximately 10-fold the temperature range already used and mastered by the engineer. Physicists are coming in contact with states of matter that up to now have been chiefly considered by theoretical astrophysicists. It will be interesting to see how quickly the engineer will follow the physicist into this new domain. ENO

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## CHEMISTRY AT HIGH TEMPERATURE AND HIGH PRESSURE

### THE "NEW" PRESSURE-TEMPERATURE FIELD

The known steady state, pressure-temperature field available for scientific exploration today is given approximately by Fig. 1. The so-called "new area" was opened for study by the author's design of an apparatus called the "Belt". Using this apparatus, the author succeeded in making diamonds from "carbonaceous material" at GE's Research Laboratory in 1954. Unfortunately (for those of us who are anxious to explore or ask questions about this new area) the apparatus is unavailable. It has been classified "Secret" by the Government because of the importance of industrial diamonds to national defense.

Pressures of 100,000–200,000 atmospheres could cause energy changes in condensed systems of the same order of magnitude as those brought about by temperature changes of 1000–2000K; i.e., these are the energies involved in ordinary chemical reactions. Thus, the variety of changes produced in matter by these pressures are comparable in number and scope to those produced in matter by these temperatures.

The broad, general effects of pressure and temperatures are diametric opposites. Application of increasing temperature to a solid system causes an increase in the average distance between atoms. The solid eventually passes through a liquid to a gaseous phase so that the final result of sufficiently high temperature at atmospheric pressure is that the atoms become separated by large distances and occupy only a small portion of the total volume. On the other hand, increasing pressure causes the average distance between atoms to decrease. Pressure (at ordinary temperatures) can cause a gas to condense to a liquid and then become a solid. Further increase in pressure can cause collapse of electronic shells. Eventually (in theory at least) pressures of the order of billions of atmospheres can cause nuclei to be forced within the critical distance of about  $10^{-13}$  cm where nuclear fusion will occur.

### Systems of Interest for Study at High Temperature, High Pressure

Almost any system is worthy of investigation in the "new" high-pressure, high-temperature area. The most fruitful field, however, will probably be found in the investigation of systems with normally "open" structures. This includes crystals whose structures are not closely packed and systems with "open" electronic structures such as the elements of the first transition group which have unfilled 3d orbitals. I anticipate continuing work will probably occur in the areas discussed below.

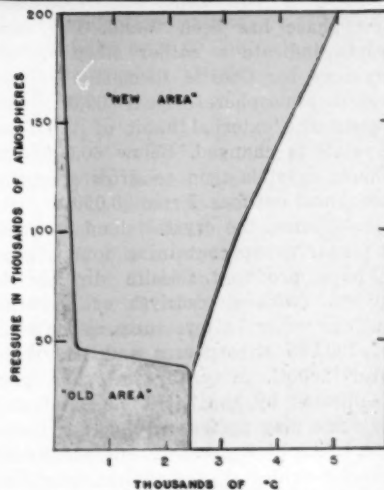
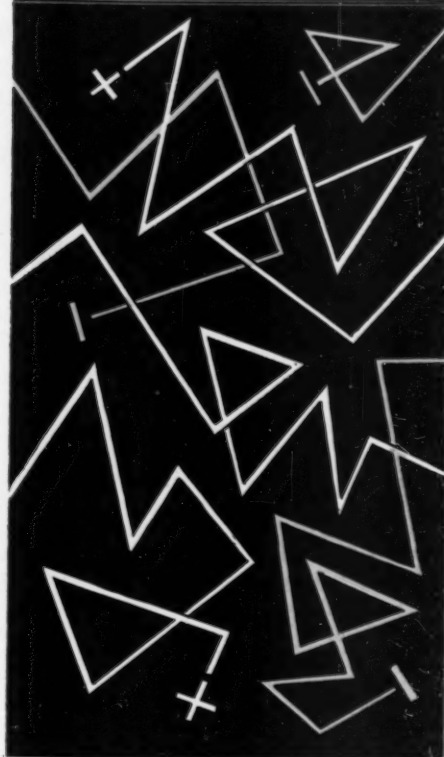


FIG. 1. Comparison of old pressure temperature region with the new region now available.

### Melting Point as Function of Pressure

The melting points of substances are profoundly affected by pressures of the order of 200,000 atmospheres; for example, the recently reported 600 degrees lowering of the melting point of germanium. Of course, germanium is an exception to the general rule that melting point increases with increasing pressure. The melting point of some refractory materials has been increased by well over 1000C by extremely high pressures. This fact makes it possible to work at higher temperatures at high pressure than would be possible at one atmosphere. As a matter of fact, it is quite possible to work with a "liquid" refractory under high pressure conditions. A liquid can flow only if it contains "holes" into which the molecules can move. At 200,000 atmospheres the number of holes in a molten refractory may be severely reduced and it will be extremely viscous.

Work on the melting points of substances at high pressure has considerable significance in that it should throw some light on the old question as to the nature of the melting point curve as pressure is indefinitely increased. Is there a critical point between liquid and solid analogous to the gas-liquid situation? Is it impossible to melt some substances—like graphite?

### Mineral Synthesis

A very interesting result of recent high-pressure, high-temperature work is the synthesis of a new dense silica, "Coesite," not found in nature. I have experimented with sodium silicate solutions at pressures to 100,000 atmospheres at temperatures near 450C in an effort to produce a silica phase even more dense than Coesite. No new phase has been found. The experiments indicate a rather steep threshold pressure for Coesite formation at 32,000  $\pm$  2000 atmospheres. Near 60,000 atmospheres the external habit of the Coesite crystals is changed. Below 60,000 atmospheres crystals tend to grow singly with hexagonal outlines. From 60,000 to 100,000 atmospheres, the crystals tend to grow in a planar group containing four hexagons. I have produced Coesite directly from quartz (without catalyst or mineralizer such as water) at pressures in the vicinity of 100,000 atmospheres and temperatures over 2000C. Mineral growth is greatly facilitated by the use of a catalyst (or, as some may prefer, a solvent or mineralizer). At high pressure, high-temperature all the oxides show sufficient solubility in water that it may be regarded as a universal catalyst for mineral formation. A very wide array of materials are effective

in catalyzing mineral synthesis from the oxides. These include urea, ammonium salts, carbonates, phosphates, sulphates, nitrates, borates and of course water.

To synthesize a mineral, the required oxides are placed with the catalyst. The pressure is raised to the desired value followed by application of the desired temperature. Temperature is then lowered followed by pressure reduction. It is not always necessary nor desirable to use oxides. Pure metals or their salts will often do. Hydrogen will often be produced if metals are used, but it manages to escape through the hot container. This continuous removal of hydrogen at high-pressure, high-temperature makes it possible to always drive the reaction in the desired direction because of the very favorable volume decreases.

Almost any mineral with a known structure, not in closest packing, presents possibilities for production of a more dense phase at high-pressure, high-temperature. Often the more dense phase will "lock-in" and remain stable when temperature is reduced to normal followed by reduction to normal pressure.

The production of many new minerals which incorporate heavy elements and the less familiar elements of the periodic table presents a particularly fruitful area for research and investigation.

Of course laboratory mineral synthesis has great import in the field of geology. Future work at extreme pressure and temperature will do much to give new information on the interior of the earth and geological processes.

### The Synthesis of Hard Materials

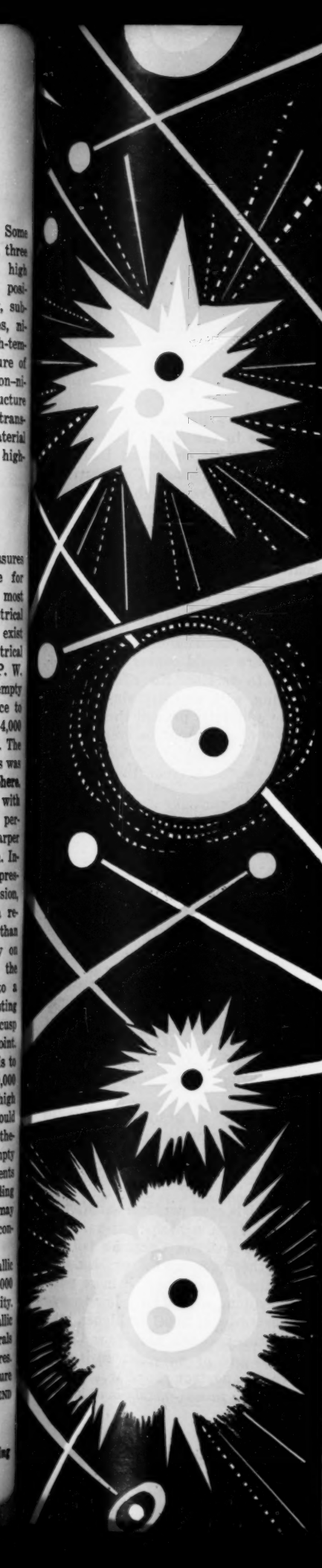
Man-made industrial diamonds will in my opinion, be a readily available commercial product within a few years. Diamond is, of course, the hardest material presently known to man. What are the possibilities of making a material harder than diamond? The answers may be found in a consideration of the qualities that make materials macroscopically hard. A necessary condition is high bond energy concentration; that is, high cohesive energy density. A subsidiary requirement is high bond symmetry in three dimensions. Diamond and graphite have the highest cohesive energy densities (ced) of any known substances. Graphite is soft, however, because it fails to meet the symmetry requirement. Materials with high heats of vaporization and small molar volumes have high cohesive energy density. Compounds with the highest cohesive energy densities are to be found among the borides, car-

bides, nitrides, oxides and sulfides. Some of these materials do not have high, three dimensional bond symmetry. Since high pressure tends to force atoms into positions that give maximum symmetry, substitution of selected borides, carbides, nitrides, etc. to high-pressure, high-temperature, may give a stable structure of higher hardness. For example, boron-nitride, which has a graphite-like structure and is slippery and soft, might be transformed into a hard, diamond-like material by use of the proper catalyst at high-pressure, high-temperature.

### Pressure Effects on Electronic Configurations

It is possible that very high pressures might affect the stability sequence for atomic orbitals. Such effects might most readily be detected in changes of electrical conductivity. Such a situation might exist in the phenomenal increase of electrical resistance of cesium discovered by P. W. Bridgman (Cesium has completely empty 5d orbitals). He found the resistance to rise rapidly to a sharp cusp near 54,000 atmospheres followed by a rapid drop. The resistance found at 54,000 atmospheres was 11 times the resistance at one atmosphere. No volume discontinuity is associated with this sharp cusp. Experiments I have performed with cesium give a much sharper cusp than that obtained by Bridgman. Indeed, it seems that if the necessary pressure could be fixed with enough precision, the peak of the cusp would show a resistance many powers of 10 higher than that at one atmosphere. Immediately on passing this sensitive pressure point the electrical resistance drops rapidly to a low value again—a most interesting phenomena. Incidentally, this sharp cusp makes an ideal pressure reference point. I think more of this type phenomena is to be expected at pressures near 200,000 atmospheres and above. The effect of high temperature on these phenomena should be studied. It might be possible to synthesize compounds from elements with empty atomic orbitals in which these elements display unknown and unexpected bonding behavior. Some of these structures may remain stable on return to ordinary conditions of pressure.

The conversion of ammonia to metallic form at pressures somewhat over 200,000 atmospheres will soon become a reality. Hydrogen is expected to become metallic near 500,000 atmospheres and minerals such as olivine near 1,500,000 atmospheres. These phenomena will result from pressure effects on electronic energy levels. END



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## HIGH TEMPERATURE MATERIALS IN HIGH RADIATION DENSITY ENVIROMENTS

Far too little is known about the behavior of high-temperature materials in the high radiation density fields present in or adjacent to nuclear reactors. These materials may be of interest for application both at high temperatures and at more moderate temperatures where immobility of lattice atoms at operating temperatures may be desired. Here's a general discussion of current problems and forthcoming nuclear applications.

Materials exposed to intensely ionizing gamma radiation fields are damaged through dissociation of the ionic and covalent bonds and the resulting fragmentation and recombination that then occurs. Fast neutrons and fission fragments may also cause extensive damage by ionization. Fast neutrons collide with lattice atoms, knocking them on with considerable kinetic energy. These positively charged secondary atoms then lose part of their energy by ionization. High velocity fission fragments are themselves positively charged and will damage materials in the same manner.

Metals as a class are not damaged by ionization, but they may be damaged by displacement collisions. Fast neutrons and high velocity fission products also lose energy by direct collision with lattice atoms displacing many atoms through a chain of displacement events. Displacement damage predominates in metals not sensitive to ionization; it also occurs in covalent non-molecular aggregates such as graphite or  $B_4C$ . The contribution of ionization relative to displacement damage in simple ceramics such as  $BeO$ ,  $UO_2$ , and  $MgO$  should also be known.

### Relative Stability of Materials

High energy particles are known to displace atoms with neutron displacement effects generally being disordering of ordered systems and expansion of the lattice. Expansion saturates in metals and leads to fragmentation in non-metals. One great problem is to be able to predict the relative stability of general types of materials as a function of dosage and exposure temperature. A spectrum of stability of materials by general types may be set up as in the table. The spectrum ranges from relatively undamaged metals to organics. The table is not complete, and no one apparently knows whether it is in the correct order.

Tests have been carried out at room temperature on both high temperature and low temperature materials.  $LiF$  is badly damaged at room temperature while  $Al_2O_3$  is not. If these and other materials are compared at the Tammann temperature where the lattice atoms are equally mobile, the results may differ widely from current knowledge. This may allow the scientist to predict high temperature performance from low temperature tests.

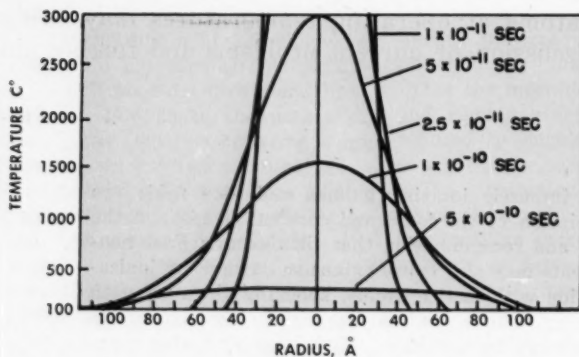
What is the behavior of  $Al_2O_3$ , one of the most radiation resistant materials near its melting point? In the *Journal of Metals*, Vol. 8, No. 5, May 1956, I have discussed the behavior of fissile materials operating in three general temperature regions: first, a low-temperature zone far below the melting point where displaced lattice atoms are not mobile and annealing does not occur; second, an intermediate zone where the displaced atoms are mobile with annealing taking place during the test period; and third a high-temperature zone where impurity atoms such as fission products and the lattice atoms are highly mobile.

For ceramics, little quantitative data are available, with thermal and electrical conductivity plus X-ray structure data predominating. Some ceramics have been irradiated and tested at low temperatures, and annealing work has shown partial recovery. The behavior of ceramics in high intensity gamma and neutron fields at very high temperatures requires study.

#### Stability of Fissile Materials

A particularly interesting phenomena is the damage introduced in metals and non-metals by a fission event which not only displaces atoms or dissociates compounds, but results in the addition of two fission products into the lattice where they act as highly undesirable impurity atoms. Common fissionable materials of interest such as nuclear fuels or poison materials are various forms of  $U^{235}$ , and  $Pu^{239}$  and  $B^{10}$ .

At high temperatures, these gases will diffuse and may agglomerate, resulting in excessive swelling as the gas atom concentrations build up to high levels. An unpublished study recently



In fissile materials the intensity of ionization and displacement of atoms is very high in the fission product track called a "thermal spike." Its characteristics have been described by H. Brooks (unpublished). Temperatures of the order of  $10^4$  K or higher may be calculated. Of chief interest: the temperature decreases while heating an increasingly greater volume of matter. The radial change in temperature with time shown here is from Holden and Wilkinson (to be published).

#### RELATIVE STABILITY OF GENERAL TYPES OF MATERIALS

Metals  
Simple Ceramics ( $Al_2O_3$ ,  $MgO$ ,  $UO_2$ ,  $BeO$ )  
Covalent Non-Metals (Graphite,  $B_4C$ ,  $SiC$ )  
Complex Ceramics (Silicates)  
Glasses  
Ionic Salts ( $LiF$ ,  $NaCl$ )  
Water  
Aromatic Organics  
Aliphatic Organics  
\*Also susceptible to fission damage at higher exposures

completed indicates that the gases in the  $Al-UAl_4$  system will diffuse in the ceramic-like intermetallic compound  $UAl_4$ ; but they do not pass readily into the metallic phase. The behavior of fission gases in ceramic compounds at very high temperatures and, in particular, gas agglomeration and swelling or cracking also need to be studied.

The kinetics and equilibrium behavior of fissionable materials and also non-fissionable materials need extensive study. The question of whether damage can be described as local thermal heating (thermal spike) or displacement and disordering through displacement collisions has not been answered. For example, stainless steel was investigated to determine if fast neutron bombardment at a low temperature would convert the thermodynamically unstable austenite to ferrite. No effect occurred when ferrite was initially missing, with an increasing effect the greater the initial concentration of ferrite present through prior cold work. It appears that a new phase cannot be created at the expense of an existing phase. For example, if local melting occurs, then the material recrystallizes from the cold zone, maintaining the same crystal habit.

A Soviet research report on uranium alloys indicates that the electrical resistivity of a two-phase U-Mo alloy changed on irradiation, indicating that more of the phase, stable at high temperature, formed. In this case, both phases existed initially and one grew at the expense of the other. Nucleation and growth appear to take place in the thermal spike zone. Investigation of similar reactions in non-metallic fissile materials is needed.

#### Miscellaneous Reactor Design Considerations

It may be advantageous to use high temperature materials at relatively low temperatures. For example, fission gases may be less mobile in a high melting ceramic than in a lower melting metal. A dispersion of a fissile phase in a metal such as the steel- $UO_2$  dispersion elements described by Weber and Hirsch (to be published) may be useful, although investigation may prove otherwise.

A fissile ceramic such as  $UO_2$  may be desirable as the fuel constituent of a fuel element. However, while ceramics are very high melting and stable, very high temperatures are also attained relative to metals due to the poorer thermal conductivity of the ceramics.

Another problem is that materials may perform satisfactorily if they are maintained continuously at a high temperature but fail on cooling down for operating reasons. Ceramics fail without plastic deformation when thermally cycled or shocked at lower temperatures, although they may be much more plastic at very high temperatures. Beryllium, a relatively low temperature metal, is ductile at temperatures of 500°C or higher, but it is very brittle at lower temperatures. Bruch has shown that the brittle-ductile transition temperature of molybdenum is raised well above room temperature by neutron bombardment, and whether analogous effects may occur in non-metals is of interest.



THEODORE VON KARMAN

## AERODYNAMIC HEATING – The Temperature Barrier in Aeronautics

Problems and tentative solutions currently applied to secure for man the enjoyment of Life, Liberty and the Pursuit of Happiness at Mach 20 in interstellar space.

The problem of heat transfer from fluids to solid bodies became of great importance as high-speed aircraft and ultra-fast missiles appeared in the development programs of military and civilian aviation. Before that, the application of heat transfer theories to aircraft structures was mainly concerned with the computation of the surface necessary to transfer a given amount of heat; for example the heat rejected by the cylinder walls of an engine into the cooling liquid or the cooling air. The concept of aerodynamic heating, however, is not quite new. As a matter of fact Galileo mentions in one of his dialogues that, according to some sources of information, the Babylonians cooked their eggs by putting them into a sling and whirling the sling around with high velocity. Galileo makes the remark that he really did not believe the story; on the contrary he believed that if the eggs were already hot they would be cooled by the air. He was right, for it can easily be calculated that to bring the eggs to boiling temperature, a circumferential speed of  $M-1.3$  would be necessary.

The usual computation of heat transfer is based on the rule called Reynolds' analogy. Reynolds was the ingenious British scientist in the second half of the 19th century who contributed fundamental ideas to the understanding of phenomena in viscous fluids. He compared the friction between a solid body and a moving fluid with the heat transfer between the same two components of the system. Evidently, the friction is a transfer of momentum; the heat transfer is a transfer of heat energy. We know that in gases, the mechanisms of momentum and energy transfer are closely similar; they are effected by the collision of molecules in laminar flow, and by eddy diffusivity in turbulent motion.

Consider first the laminar case which is accessible to exact calculations. Both the transfer of momentum and the transfer of heat take place in the narrow domain near the wall of the moving body, the boundary layer. In the case of supersonic flow with moderate Mach number, the flow of a compressible fluid in the boundary layer can be computed without much difficulty.

First assume that the body is thermally insulated so that heat transfer is prevented. Then theory and experiment show that

the temperature of the air at the surface is elevated practically to the same degree corresponding to the temperature rise through normal impact—the adiabatic stagnation temperature. This relation, first found by L. Crocco for compressible fluids with Prandtl number one (the ratio between kinematic viscosity and temperature conductivity), means physically that the heat produced by viscous forces between adjacent layers with flow velocity decreasing toward the body surface is equal to the heat which would be produced by decreasing the velocity by an adiabatic compression process.

This fact was not clear in the past to many engineers. In the case of a gas or steam turbine, for example, some designers believed that if the gas is expanded to high velocity and low temperature between the combustion chamber and the moving turbine blades, the blades would be exposed to the lower temperature corresponding to the expansion. In fact, the gas temperature at the blade surface will be equal to the stagnation temperature, a temperature comparable with that in the combustion chamber. If the Prandtl number is different from unity, the "recovery temperature" will be slightly less, approximately proportional to the square root of the number.

The second important result of theoretical and experimental research is the fact that, if the body is not insulated, the heat transferred from the gas to the body is proportional to the difference between the recovery temperature and the wall temperature, instead of the difference between the ambient and the wall temperature as is the case at low velocity. This fact changes the whole physical picture as the Mach number increases. For air, the ratio between stagnation and ambient temperature is equal to unity plus one-fifth of the square of the Mach number. Assume, for example,  $M-4$ ; then for 300K ambient temperature the stagnation temperature becomes equal to 1260K and for  $M-16$ , 15,700K. In other words, assuming the same heat transfer coefficients, the body would receive a heat input as if it were at rest in a medium of 15,700K.

In a turbulent boundary layer, the recovery temperature is of the same order as in laminar flow; however, the heat transfer coefficient corresponding to Reynolds' analogy is several times

larger than in the latter.

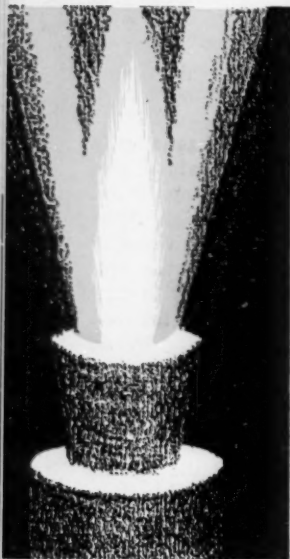
This general consideration shows that designers have every reason to worry about the effect of aerodynamic heating on the structure, the crew and the passengers, and the equipment carried in the craft.

The situation becomes uncomfortable at moderate Mach numbers of say two. One may note with some satisfaction that the discomfort for the electronic equipment begins earlier than for the human pilot. Indeed, a good pilot's brain still works satisfactorily at a temperature at which an electronic brain becomes completely useless. The first component in the system needing cooling is the electronic equipment, especially because of high temperature sensitivity of transistors.

#### Effects of Aerodynamic Heating on Structures

Main sources of danger from aerodynamic heating of a structure include:

- Reduction of the elastic moduli, lowering the resistance of all structural members against buckling and analogous phenomena of structural instability.
- Reduction of yield point, ultimate stress, and especially fatigue stress causing breakdown of the structure.
- Increasing rate of creep which also reduces the resistance of structural members exposed to buckling. Creep may concentrate high loading on members not designed for such loads.
- High thermal stresses caused by uneven thermal extension of structural members.



During the past 15 years, many millions of dollars have been spent on high-temperature alloy development with but few fruitful results. Last month, General Electric, Climax Molybdenum and Westinghouse made almost simultaneous announcements. GE released a vacuum-melted nickel-base alloy, M-252, for extended operation under load at 1240F. Climax Molybdenum issued a 427 page summary report of a six year Navy sponsored research program on arc-cast molybdenum-base alloys some of which have significant strength at 1600F; and Westinghouse revealed a "predesigned" cobalt-nickel alloy, "Nivco," with an ultimate tensile strength of 100,000 psi at 1200F. Nevertheless, in terms of designs awaiting materials capable of withstanding destruction at 1800F and higher, the best efforts of an army of metallurgists and engineers have been almost for naught; the seemingly inherent limitations of the materials remain in control of the situation.

What are the possibilities with ceramics?

- Loss of torsional wing stiffness, caused by uneven temperature distribution.
- In extreme cases, melting away of parts whose melting point was exceeded by high local temperatures.

#### Design Approaches

From the designer's viewpoint, the main problem is to determine the temperatures which can be expected in definite flight conditions with distinction between stationary and transient states.

In continuous flight at constant speed (flight in a stationary state), an equilibrium is established between heat input and heat emission. Heat input per unit time and unit surface equals the product of the effective temperature difference and the heat transfer coefficient. Effective temperature difference is the difference between recovery temperature and wall temperature. The heat transfer coefficient largely depends on the density of the air surrounding the body and therefore on the altitude. Hence, to find out the possibility of continuous flight without facing the dangers mentioned above, two parameters must be considered: Mach number and altitude.

Heat emission in continuous flight is first the radiation which varies at a rapid rate as the surface temperature increases; radiation also varies with the altitude. Unfortunately, the radiation at surface temperatures permitted by current materials permit represents a small amount in comparison with the heat input to be expected. Artificial means are thus necessary to

## DUCTILE CERAMICS

PHIL R. PARKER,

Professor of Metallurgy, University of California, Berkeley

The prospects for substantial progress with metals are not good. The question actually arises—if metals are inadequate for use above 1800F, is there a possibility that ceramic materials can be used for gas turbine components?

Refractory ceramic materials are strong at high temperatures but they also have a seemingly inherent limitation—brittleness. Present materials suffer so severely from this handicap that they are useless as gas turbine materials. Attempts to impart some toughness to ceramic bodies by intermixing particles of metals and ceramics resulted in "cermets". It was hoped that such mixtures would have strength approaching those of ceramic bodies and would have toughness comparable with metals. Unfortunately, the union brought forth the worst traits of each constituent; cermets are discouragingly brittle and are only slightly stronger than metal. Results of the research efforts to date have not been encouraging.

Is it then feasible to try other means of making ceramics tough or even ductile? It appears to be within the realm of possibility. Ductility in crystalline materials depends upon a number of factors. One of the most important is crystal structure. Simplicity of the structure is an essential feature because slip requires translation of atoms from their original sites to nearby equivalent locations. If this can be accomplished by a sharp, linear movement, slip can occur and ductility is possible. If, however, movement of an atom from one site to an equivalent neighboring location is impaired by the presence of an unlike intervening atom, as is often the case when a structure is complex, then slip is improbable and brittle behavior occurs.

#### Ionic Crystals

A review of the behavior of some real materials will serve as an illustrative example. Simple compounds such as the alkali-halides exhibit plastic behavior exactly like that of metals. For example, sodium chloride under certain conditions can be bent or stretched. A tensile specimen made from a single crystal of

reduce the heat input or to transfer heat from the airplane or missile to the surrounding space.

What are some of these possible means?

- Reduce the input; for instance, some favorable effect can be expected from insulation between the external surface and the inner structural elements.
  - Provide internal cooling by means of an expendable coolant (for example, boiling water which evaporates). In such cases the amount of coolant needed can be reduced by insulation.
  - Arrange internal cooling with refrigeration of the coolant. Here the amount of coolant is reduced, but fuel must be expended for refrigeration.
  - Apply transpiration or sweat cooling, consisting of pumping of a liquid, gas or vapor through a porous skin.
  - Finally, use mass transfer cooling, consisting of a coating which sublimates or chemically dissociates with increasing temperature, thus keeping the temperature under the allowed limit.
- In almost all cases the cooling requires increase in weight; however, for limited flight time the weight increase might be within reasonable limits.

The situation is more favorable in very high altitude flight when heat input is relatively small or even negligible. Thus, satellites supposedly will have little difficulty in maintaining their thermal equilibrium during the period of their two hours' flight around the globe. Also, some high altitude missiles probably can get along with compartment cooling which would dissipate the heat produced by their own equipment.

In transient flight, no great difficulties are expected for the period of accelerated flight of missiles. Heat capacity of the structure can probably be increased in such a way that the surface does not attain ultra-high temperature during the limited time interval concerned.

In the case of a ballistic type of missile, for example, the skin is heated until an equilibrium between heat input and radiation loss is reached. Fortunately, the heat input decreases with increasing altitude; and, as mentioned above, it becomes negligible outside the atmosphere. Radiation continues to cool the missile until it starts its period of return into the atmosphere. Then heat input increases faster than radiation, and we face the "re-entry problem".

A re-entry Mach number between 12 and 20 presents us with one of the most difficult problems one can imagine. This extreme hypersonic velocity produces a shock which generates temperatures comparable with stagnation temperatures of the order of 12,000-16,000K. The air dissociates at these temperatures, thus posing an extremely complicated problem of Aerothermochemistry. Magneto-aerodynamics is eventually involved if ionized particles are present.

This problem constitutes a challenge to the best brains working in these domains of modern Aerophysics. The satellite as presently conceived does not face the same problem; if telemetering and means of observation will work satisfactorily, we can let the missile burn like a meteorite created by the Lord.

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this salt will undergo work hardening and the shape of a stress-strain curve will be similar to one obtained from a metal crystal. Sodium chloride forms a cubic crystal with alternate cube corners occupied by like ions; the nearest identical positions are diagonally across the cube faces. Thus it is to be expected that if slip occurs, it will take place in one or more of the face diagonal directions, and this is the case.

The story is not quite so simple, however, because sodium chloride is ductile only under very special conditions. Normally it is very brittle and fractures by cleavage (along cube faces) when loaded. The conditions promoting plasticity in sodium chloride were discovered by Joffe in 1924. He found that it became ductile when immersed in unsaturated warm water. However, when the salt concentration was greater than about 80% of saturation, the crystals remained brittle. Joffe explained his results in the following way: if prepared surfaces are presumed with good reason to contain numerous microcracks which nucleate cleavage fractures when the load is applied, warm water dissolves the surface layer, thus removing the cracks with their attendant stress concentration. Under these conditions, flow occurs rather than the brittle fracturing. The concentrated solutions, it was thought, do not dissolve the surface and hence do not remove the cracks. Some recent experiments in our own laboratory have shown that the explanation offered for the behavior of salt in concentrations is probably invalid. In this case, potassium chloride was used for the experiments. It behaved exactly like sodium chloride, but it was somewhat easier to work with. This salt is also brittle in air and in the saturated sodium chloride solution. It is ductile in warm dilute solutions. A potassium chloride crystal immersed in water, began to exhibit ductility within three seconds after immersion and reached a condition of maximum ductility in about two minutes.

This significant experiment was performed with a crystal made ductile by water immersion and was transferred directly from the water to a saturated solution and tested therein for ductility. According to the accepted theory, crystals treated in this manner should retain their ductility because the notches have been removed by solution in the water. Actually, ductility diminished rapidly and in less than 10 minutes the crystal was brittle again. Experiments of this sort are interesting because they show that ionic solids as well as metals can be ductile.

However, many more fundamental investigations of this sort will have to be made before we can say whether or not high temperature "ductile ceramics" can be made. Although information about the effect of environment or surfaced condition on brittleness is rather scarce, there is one other investigation that may be of interest.

The role played by surface energy in the fracturing of brittle materials is still uncertain. An investigation designed to illuminate this problem was recently conducted at the University of California. Ice was selected as the material to be tested because it is free from complication, such as electro-chemical corrosion and also because there is a wealth of surface energy data for water both with and without additives. Some experiments were made with a cantilever-beam type of specimen,  $\frac{5}{8}$ " x  $\frac{1}{4}$ " in cross section and several inches long. Specimens of this type were immersed in isopentane at  $-1^{\circ}\text{C}$  and loaded as a cantilever beam. A load of 450 grams would not cause failure, even though it remained on the specimen for 24 hours. When one percent of isobutyl alcohol was added to the isopentane and the test repeated on identical specimens, failure occurred in only 40 minutes. Isobutyl alcohol is a surface active agent—it lowers the water isopentane interfacial energy to 2.1 erbs per cm squared.

Since ice fractures by cleavage, these results may be helpful in developing an understanding of brittle behavior. Additional experiments with other additives produced surprising results. For example, when aerosol OT which lowers the water isopentane interfacial energy to less than one erb per square centimeter was added to isopentane, the fracture strength of ice was not reduced. Instead this material endowed the ice with ductility. Instead of breaking, the ice began to flow slowly and the specimen bent through an angle of 15 degrees within a 24-hour period. Here again is a clear-cut example of brittle material being made ductile by a slight change in its environment.

The brittleness of ceramic materials is not an inherent property common to all non-metallic inorganic compounds. Certain solids can be made ductile merely by changing the surface condition. The reason for the change in behavior is at best only partially understood. Fundamental research has been long neglected in this field. Who knows what surprises are awaiting the imaginative research man—perhaps ductile refractory ceramics can become a reality instead of a dream.

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## Among Those Present



(left to right) Dr. Pol Duwez, professor of Mechanical Engineering, California Institute of Technology; Dr. Theodore von Karman, chairman, Advisory Group for Aeronautical Research and Development, NATO; and E. Finley Carter, Associate Director and chairman of the Management Committee, Stanford Research Institute.



Dr. William D. Smiley, associate ceramics technologist, SRI, (left) chats with Wolfgang Finkelburg, Siemens-Schuckertwerke Ag., Erlangen, Germany. Third photo: Dr. Clifford Weber, Manager, Materials Engineers, General Electric Company.



### HIGH TEMPERATURE

continued from page 23

Solid machined shapes can be used just as conveniently as granules to take advantage of the high contact resistance between solids. The graphite elements nest together, giving a reasonable stability to the column. Various shapes can be used to provide ends for a black body section, or sighting holes. The arrangement has an advantage over a solid tube in having a higher resistance, since the greatest resistance is at the junction of the segments and lower current transformer equipment can be used. On a commercial scale, a furnace designed with this type of heating element could have a better power factor and thus a less costly transformer because of the lower current requirement.

To attain the very highest temperature possible with a solid resistance heating element, one must necessarily use the highest melting solid material—a four-to-one mixture of tantalum carbide with hafnium carbide and has a melting point of 3914°C. MacPherson thinks furnaces using these very high melting point materials will become more common as the availability of fabricated shapes is made possible through current developments in high temperature materials. However, these high melting point carbides suffer from the defect that carbon evaporates from them rapidly at the highest temperature. Thus, their utility is greatest when the furnace atmosphere is rich in carbon vapor.

### Electric Arc Heating

The most useful feature of arcs is the great concentration of the energy released and the resultant high temperatures produced. The voltage drops multiplied by the arc current density give the concentration of thermal energy released in an arc. Today, there are two principal types of commercial arc furnaces: open arcs, and submerged arcs. The open arc furnaces are used primarily for melting metals. Submerged arc furnaces are used principally for reacting granular or powdered materials at high temperatures.

A recent commercial development of an arc furnace melts reactive metals, such as titanium and zirconium in an inert gas

atmosphere, using water-cooled copper crucible walls. Thus, the metal being melted, in effect, becomes its own crucible.

Looking to the future, MacPherson suggests that arcs be used more widely and more imaginatively for a number of special laboratory and experimental applications which require a highly concentrated source of heat. The arc may be thought of as providing two types of concentrated heat: one at the anode surface and the other in the arc stream, and each of these will have their special application.

For example, use of the high surface heating rate is made in spectroscopic analysis for the vaporization of refractory compounds into the arc stream. MacPherson showed a so-called "boiler cap" spectroscopic electrode used as a positive electrode in a d-c arc—in effect, a furnace having a surface generation of heat of 1–2kw per sq cm at the upper surface. The penetration of heat to the bottom of the cup depends upon heat conduction through the walls of the cup downward. In other applications, surface heating by this mechanism of anode voltage drop may easily reach 5–10kw per sq cm, although at the highest heat, the anode surface of even the most refractory materials evaporates rapidly.

MacPherson discussed heating of gas streams and high frequency electronic torches, but the one electrical means of reaching high temperatures that intrigued him was the method of using electron bombardment in a vacuum. It is well known, of course, that X-ray tube anodes become hotter than desired because of the bombardment with low electron currents moving at high velocities under the influence of the high voltage in the tube. This method has been used for a number of different lab purposes, one of the most recent being for the floating-zone melting of solids. One set-up he described was the work of others in which tungsten and rhenium was melted and re-crystallized. The apparatus was reasonably simple, since it is not too difficult to obtain a few thousand volts at a few tenths of a milliampere to provide in the neighborhood of one kilowatt power input on a very concentrated region. This method is applicable to samples which are not very highly conducting, since the current required is not high and the voltage available is high. It does, of course, require a good vacuum for operation.



(left to right) Dr. Heinz Fischer, Chief, Electro-optical Section, Air Force Cambridge Research Center; J. C. R. Kelly, Westinghouse Research Laboratory; Richard H. Graham, Division of Reactor Development, U.S. Atomic Energy Commission; A. V. Grosse, President, Research Institute of Temple University.

## INDUCTION FURNACES

Frank T. Chesnut of Ajax Electrothermic Corporation speculated on the probable role of induction furnaces in high temperature applications. "I should like to know many things which, though perhaps known to others, are not known to me . . . Carbon and graphite products are probably the most inviting because they permit the highest controlled temperatures in furnaces of large dimensions. We are told graphite 'vaporizes at 3600C', but does it have a vapor pressure perhaps over a very wide range, and how does that pressure vary with partial pressure or increments of vacuum?"

"I would try to find out why graphite muffles of present composition disintegrate or crumble when operated for long periods at high temperature to learn whether perhaps it is an oxidation process controllable by sealed containers or special atmospheres, or a vaporization of the materials presently used as a bond. I would make up carbon or graphite assemblies of various compositions, various grain sizes and various bonds and I would study these at high temperatures under ordinary and at partial pressure conditions. I believe that if the graphite load or muffle would remain intact, uses would be found for the high temperatures which could be maintained, perhaps for the continuous production of graphite for making carbides or the like.

"I would study graphite vapor and graphite condensate, means for coating articles with such condensate and the subsequent testing of such articles themselves under all imaginable conditions; because articles coated with graphite in this way might be vastly superior to articles made of graphite in conventional ways. I would study oxides and cermets to see if any were capable of being heated by high frequency induced currents and of retaining their form at very high temperatures. Muffles made of such materials might be very useful for high temperatures where non-carbonaceous atmospheres are desired. They might have to be preheated to a point where their conductivity would be sufficient to afford further heating by induction.

"Not only would I check vaporization processes for graphite at reduced pressures, I would be sorely tempted to study the heating of graphite at greatly increased pressures. The National Carbon Company has melted graphite in an arc furnace at a pressure of 2500 pounds per square inch and GE has made tiny

diamonds . . . Maybe with high temperature, high pressure and the control available with the induction furnace, conditions might be met for growing one of the more valuable types of carbon crystal. It would be difficult but might not be impossible to so shield an inductor that high temperatures and high pressures heretofore untried might be reconciled.

"I can think of many tests which could be made in an induction-furnace-adapted wind tunnel but I suppose most already

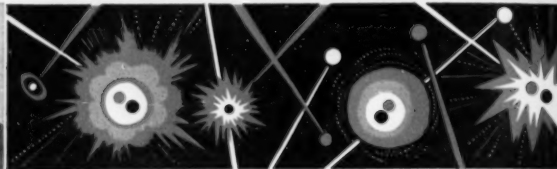
## THE PROBABLE ROLE OF INDUCTION HEATING

Approx. Temp. Range (°C.)	Application	Remarks
800-3600	Testing jet, atomic and rocket engine parts.	Induction heating applied to mechanical testing machines, wind tunnels, etc.
1200-2600	Formation of carbides.	Induction heated graphite muffle furnaces.
1400-1600	Sintering and hot pressing carbides, cermets, etc.	Induction heated graphite muffle furnaces and presses.
1600-1800	Melting of super alloys for jet, atomic and rocket engine parts.	Induction melting, vacuum induction melting, combination arc and induction vacuum melting.
1600-1800	Carbon reduction of silica	Induction heated graphite muffle furnaces.
1800-2100	Carbon reduction of magnesia	Induction heated graphite muffle furnaces.
2000-3000	Graphitization	Induction heated graphite muffle furnaces.
2200-3000	Purification of graphite	Induction heated graphite muffle furnaces.
2612	M. P. molybdenum	Induction heated molybdenum muffle furnaces.
3380	M. P. tungsten	Induction heated tungsten muffle furnaces.
3600	* Vaporization of graphite	Induction heated graphite muffle furnaces.

have been tried. The wind tunnel would, of course, have to be specially adapted for the induction heating equipment. Size might be an important factor. The heating cycle might have to be very fast. The inductor might have to be used then withdrawn before the test, or it might have to be solidly built and specially cooled so that large amounts of energy could be imparted quickly to the test piece before radiation could affect the inductor adversely. Perhaps the inductor would be split in

half or segmented so that after a heating operation, the parts could be withdrawn into a smooth wall of the tunnel . . . It is a more or less general belief that if suitable high temperature muffles can be maintained, carbides may be formed in a continuous process. Or perhaps, at higher temperatures metals can be competitively reduced from their oxides or ores. It is believed that work along these lines probably could stand a great deal of study."

Richard H. Graham  
Division of Reactor Development, A.E.C.



## High Temperature Nuclear Heat Sources

Conventional pressurized water reactors have operated successfully for long periods at temperatures of about 650F. Many engineers consider it within the realm of existing design techniques to operate liquid-metal-cooled reactors at temperatures of 1500F. The Atomic Energy Commission is examining the possibility of developing reactors specifically for sources of high temperature heat for chemical processing. The initial target temperature is 2500F. It is probable that such a reactor using ceramic fuel elements can be built to heat helium or other noble gases to that temperature. Whether such materials of construction are compatible with the process streams of interest is unknown today. It appears economically attractive to drive certain endothermic reactions in the reactor core itself. Among these are production of acetylene from natural gas, production of hydrocyanic acid from methane and ammonia, and gasification of coal. The latter possibility is being studied by the Bureau of Mines.

Effects of radiation catalysis on these reactions are unknown but they may be beneficial. Problems are formidable: erosion, thermal shock, process stream activation, channeling and packing of solids, and fission product diffusion through the fuel element walls. Also, such a "process-heat" reactor will require new equipment for handling high-temp gases.

If no techniques become available soon for processing directly in the reactor, it will still be valuable to attempt to operate a reactor with an inter-gas coolant to a temperature as high as 2500F. This will demonstrate, first, that a reactor for operating at these temperatures can be built and, secondly, the control and nuclear operating characteristics of such a device. Direct application of a high-temperature, inert-atmosphere, closed-loop reactor in power applications such as steam superheating and driving gas turbines are possibilities.

In exploring the problem of how to obtain very high temperatures from the fission reaction, one must search for techniques of transferring the kinetic energy of fission directly to the working fluid, all of which are gases at the temperatures we wish to obtain, without dependence on the materials of construction as in conventional heat transfer. A mechanism worthy of further investigation in this system is the Nernst effect, in which a gaseous molecule enters into endothermic dissociation at the heat-exchanger wall and, after returning to the process steam, recombines and gives up energy. This heat transfer by dissociation may allow big increases over existing heat-transfer flux rates.

One possible technique is to employ thin surfaces of fissionable material in such a geometry as to attenuate the fission products in the preheated working fluid. In this way the heat may be created in the fluid immediately prior to its exit from the reactor. Thus, the temperature of the fluid can exceed the temperature of the reactor. The obvious drawback is the fission-product contamination of the process stream, although it is conceivable that decontamination and hold-up may reduce the activity to acceptable levels. Another, somewhat more "long-range" scheme, would constrain the reaction between the gaseous ions to the center of a vessel by electrical or magnetic fields, so that by the solid angle involved, the heat flux on the containing vessel is below its threshold of failure.

It is perhaps conceivable to constrain a mixture of gases including fissionable materials, such as uranium hexafluoride, and a moderator, such as carbon tetrafluoride, to the center of a containing vessel so that the reactor core would essentially be surrounded by space. In this fashion, the temperature of the cloud of gas could exceed the allowable wall temperatures. The process stream gas might be introduced directly with the fuel and moderator gases. Here again direct fission-product contamination of the process stream exists.

### Forecast for the Future

In attempting to forecast some logical schedule of attainment of increasing temperatures from nuclear sources, I am at somewhat of a loss because of the large gap between those temperatures currently available and expected within the next few years under steady-state conditions in contained vessels, and those available in pulsed, weapon-type reactions in free air.

I believe that we will obtain nuclear source temperatures of 2000K within the next five years under static conditions in reactor experiments of advanced design. Such an achievement will require a considerable technological effort including advances in materials techniques; but it appears to be a reasonable goal. The temperatures available today in pulsed events in space are about 20,000K from a fission weapon fireball 45 feet in diameter.

Techniques of arc discharge and exploding wires have produced temperatures in excess of  $10^5$ K, again in pulses. The availability of these sources may indicate the way for more elaborate experiments to utilize the greater amounts of energy available from nuclear sources.

## HIGH TEMPERATURES BY SHOCK WAVES

Shocks produced for quantitative study have usually been generated in a pressure-driven shock tube or by the detonation of high explosives. The shock tube can be operated in the laboratory in a highly reproducible manner, instrumentation is relatively simple and the cost of operation is low. Explosives for shock generation requires the work to be in the open, and the cost is relatively high. Explosives, however, represent the only practical method at present by which strong shocks can be produced in solids and liquids. With sufficient care in experimentation, the results, report G. E. Duvall and M. C. Kells of SRI, are very precise and reproducible.

The shock tube is a long metal tube divided into two sections by a thin diaphragm. The gas on which studies are to be made is introduced into the low-pressure section and the driver gas into the high-pressure section. When the diaphragm is ruptured, a compression wave, which rapidly develops into a shock, moves into the low-pressure region ahead of the interface between the driver and low-pressure gas. Shock strength produced in the tube increases with the pressure ratio across the diaphragm and with the sound speed in the driver gas; hence hydrogen and helium are often used as driver gases for producing strong shocks.

Extremely high temperatures in solids, liquids or gases can be generated provided the shock strength is great enough. Production of sufficiently high temperatures to stimulate new research has become a routine matter only in the case of gases. The simplest gases are monatomic and at least one such, argon, has undergone extensive study. Polyatomic gases are more complex in the matter of establishing equilibrium behind the shock front because of the vibrational and rotational modes of motion not found in the monatomic gases. They are furnishing, nonetheless, according to Duvall & Kells, fruitful problems for research.

## REFRACTORY COATINGS

Thus far, most coatings have been developed, not to contain heat, said S. W. Bradstreet of Armour Research Foundation, but to resist chemical, mechanical, or electrical stresses at moderate temperatures. The reason is an understandable one, for if the low thermal conductivity of zirconia is wanted to restrict heat transfer, a zirconia brick will more effectively restrict it than a zirconia coating. The few exceptions to this have been those in which a saving in weight or space is vital—turbojet and afterburner components, rocket motors and nozzles.

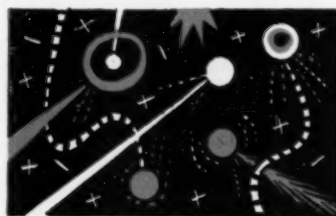
As useful temperatures rise to the range above 2000K, the value of coatings is more apparent. The higher the temperature of application, the greater is the potential temperature gradient in the coating, and the more valuable even a very thin coating may be because of relatively low absorptivities and conductivities of ceramic materials. There is little reason for using a zirconia coating on a cold-flowing die; there appear to be excellent reasons for using it on a hot-forging die. A ceramic coating on a diesel piston head may lower the operating temperature of the piston more than 100C, and the momentary temperature gradient across a ten-mil alumina rocket nozzle coating may approach 100C.

When prolonged exposure to heat is involved, the coating must be thicker; increased coating thickness introduces additional problems. The ordinary difficulties involved with slight differences of thermal expansivity between coating and substrate,

which are now operating at quite different mean temperatures, are magnified. Moreover, the thick coating itself begins to show the tendency toward brittle failure which is characteristic of ceramic bodies.

At present, coating thicknesses lie in the compromise range where the ceramic layer is thin enough to adhere to the substrate, yet thick enough to reduce heat transfer significantly. Very recently thicker coatings have been made by using several different layers in the coating, and by introducing metallic fibers into the ceramic matrix.

In coating technology Bradstreet noted that empiricism has been forced upon us by ignorance of the thermal and mechanical properties of coating and substrate, and of the temperature levels and gradients which exist. Even more confusing are the many permutations and combinations of coating compositions, application techniques, and substrate composition and surface preparation. These lead to certain apparent anomalies which require research more fundamental than has yet been brought to bear. Some of the questions Bradstreet posed: why should the microhardness of some flame-sprayed coatings be influenced by the hardness of the substrate, even when the coating thickness exceeds one-eighth inch? How can a coating exist which has an apparent porosity of more than eighty percent? Why do flame-sprayed aluminas exhibit higher dielectric constants than sintered aluminas of the same purity and density? How can a flame-sprayed zirconia coating be almost equally adherent on Pyrex glass, electrode carbon, and mild steel? How do some coatings undergo phase changes without losing their adherence? Why do some materials, as coatings, undergo crystal growth at lower temperatures than they do in solid form, while other materials show an opposite behavior?



## REACTIONS AT HIGH TEMPERATURES

There are two important considerations concerning interactions of systems and their environments at high temperatures; (1) closed systems very often attain equilibrium in times short compared to those required for experimental investigation or technological application and (2) in such cases where equilibrium is to be attained all that would be needed to predict behavior would be complete thermodynamic properties for the components of the phases involved. The acquisition of the complete thermodynamic properties said R. K. Edwards of I.I.T. faces many experimental and interpretational problems. The high temperature investigator might well be distressed by the increased complexity of experimental work as one goes to higher and higher temperatures. The possibility of any single investigation being by itself inclusive, seems to be quite low.

T. S. Laszlo of Fordham University outlined two possible approaches to the problem of selecting materials to contain high temperatures:

- Selection of an environment which will not react with the high temperature material.
- Avoidance of any foreign matter in the high temperature zone.

The first step in such a selection is a thermodynamic consideration as to whether a reaction between the high temperature material and the material in its environment is likely to occur. The free energy value for the reaction is the most important indicator. Calculation of free energies for high temperature reactions required heat capacity- and equilibrium-vapor pressure data for all reactants and products at the reaction



Tibor S. Laszlo, Director, High Temperature Laboratory,  
Fordham University

temperature. Laszlo pointed out that values for most cases are not available; published values seldom go beyond 2000C for a single compound and for reactions between various compounds only to 1400C. However, it is possible to calculate approximate values of free energy at high temperatures.

All reactions proceeding between the reactants at high temperature have to be considered when calculating free energies. Again, more information in this respect is needed. All possible changes in phase or crystalline form have to be investigated at high temperature and their heat balance measured. After all this information becomes available, other phenomena which tend to change equilibrium conditions have to be considered. Dissociation and vaporization of reactants and products may greatly influence the conclusions reached from free energy values. And here, again, Laszlo reported the need for actual measurements.

All these theoretical considerations would determine whether a reaction is likely to occur. The final proof, however, has to be experimental. Investigation of the sample and environment before and after the heating will give the definite answer to the main problem: "Can a material be heated to the desired temperature in a given environment?" An example of this approach was a project to find a suitable container for the melting of English China clay. A number of highly refractory materials were tested (zircon, zirconia, alumina, tantalum, thoria, magnesia, titanium carbide) until finally titanium nitride proved satisfactory at 2000C.

Even when theoretical considerations and testing show that interaction does not take place, the possibility is not completely excluded as long as both material and environment are in contact at high temperatures. The equilibrium constant may be extremely small, but minute amounts of contaminants may enter into the sample during heating. In certain cases, such as growing single crystals for electrical and optical measurements even minute amounts of contaminants have to be avoided. Only very few sample-container combinations give the assurance that no interaction whatsoever will take place at high temperatures. The only way to exclude all possibility of reaction, according to Laszlo, is to remove all foreign matter from the environment of the high temperature material.

#### Reaction Kinetics

At high temperatures a metal can react with gases, liquids, or solids—more simply stated: at high temperatures a metal reacts. Three principal reactions can occur between a metal and its environs: (1) a new phase, composed of the metal plus the environment, can form and often precipitates on the metal surface, (2) the metal can dissolve in the environs (or evaporate in the case of gaseous environs), and (3) the material of the environs can dissolve in the metal; and, of course, combinations of these reactions can occur. D. Cubicciotti of SRI talked about the kinetics of these reactions at high temperatures.

The oxidation of a metal is characterized by the shape of the curve of amount of reaction as a function of time. Thus the three most common oxidation types are: (a) linear (amount of reaction proportional to time), (b) parabolic (amount of reaction proportional to the square root of time), and (c) logarithmic (amount of reaction a log function of time).

The linear type of oxidation generally occurs when the oxide formed is volatile (as with  $\text{MoO}_3$  at higher temperatures) so that the oxide is removed and does not affect subsequent oxidation; and when the oxide is porous or nonadherent (Na, Ca) so that it does not obstruct the access of the oxygen to the metal surface. If the volume of oxide produced is less than that of the metal consumed, the oxide will crack and a linear type of oxidation ensue. If the volume of oxide is greater than that of the metal consumed, the oxide will often remain continuous and hinder subsequent reaction. In such cases a parabolic type of oxidation is often obtained. A continuous layer of oxide forms on the metal and further oxidation must occur by diffusion of metal or oxygen through the oxide layer. As the layer becomes thicker the diffusion rate decreases as does the oxidation rate.

Cubicciotti reported that one investigator has proposed an electrochemical mechanism for parabolic oxidations and has related the oxidation constant to the independently measurable quantities, the electrical conductance, transport numbers, and free energy change of oxidation. Another has applied the absolute reaction rate theory to the diffusion process and has related the parabolic oxidation rate constant to the free energy change to form the activated complex during the diffusion process. Estimated values agree with the experiment for nickel oxidations.

#### Oxidation of Metals

Some metals have been found to oxidize parabolically up to a certain temperature (or better, up to a certain thickness of oxide) and linearly beyond that. Among the metals that have been found to exhibit such behavior are cerium, calcium, thorium, uranium and, recently, tungsten.

For several of these oxidations the activation energies for the two types of reaction have been found to be almost equal. This indicates that the rate-determining steps of the two types of oxidation of the same metal are similar. Since in the parabolic oxidation diffusion through a growing oxide layer is rate-determining, it is reasonable to assume that in the linear oxidation diffusion through which the diffusion occurs is fixed.

In the oxidation of a metal that undergoes a parabolic to linear transition, the oxidation starts as a normal parabolic oxidation; but when the thickness of the oxide reaches a critical value, it is no longer continuous but cracks or becomes porous. The oxidation then proceeds as a linear oxidation with diffusion through the oxide layer of constant thickness being rate-determining.

Recently, this concept has been formalized and applied to the oxidation of tungsten. Analysis of experimental results permitted J. Wagner to calculate the critical oxide thickness for the transition, as well as the parabolic and linear rate constants at different temperatures.

Cubicciotti's opinion is that in all linear oxidations the rate determining step is diffusion through a rapidly formed oxide layer of constant thickness. A normally linearly-oxidizing metal-calcium was found to oxidize parabolically at low temperatures (below 400C).

#### Oxidation of Alloys

Since the oxide coating formed on an oxidizing metal determines the rate of oxidation a serious change in the oxidation rate of a metal can only be caused by a change in the nature of the oxide. A good method for reducing the oxidation rate of a metal is to add an alloying metal which reacts to form an oxide that reduces the oxidation rate.

In a recent paper Rengstorff described his search for an oxidation-resistant alloy of molybdenum. Molybdenum is especially susceptible to oxidation because the oxide  $\text{MoO}_3$  is volatile above 850F, and at 1460F a sudden increase in the oxidation rate is found, presumably due to the melting of  $\text{MoO}_3$ . At 1800F the metal is lost at a rate of 0.1 inch in four hours (as contrasted to a 0.1 inch per year oxidation rate for a satisfactory Cr-Fe-Ni alloy).

Rengstorff looked for an alloying agent that would either form a stable molybdate and reduce the evaporation of  $\text{MoO}_3$  or form an impervious oxide and prevent its formation. He reported the results of many alloys tested, one of which were sufficiently oxidation-resistant. However, he found that nickel and calcium additions did reduce the metal lost by one hundred-fold in both cases by forming stable molybdates.

#### Catastrophic Oxidation

A type of oxidation found with certain alloys containing an appreciable fraction of molybdenum has alternately been called catastrophic oxidation, rapid oxidation, and accelerated oxidation. In these oxidations the reaction will start according to a parabolic oxidation and then suddenly proceed to a rapid linear oxidation. It is generally conceded that this phenomenon is caused by the formation of a liquid oxide (mostly  $\text{MoO}_3$ ) when the rapid reaction starts. The same type of attack can be induced if  $\text{MoO}_3$  is introduced from the gas phase (in the absence of Mo in the metal) and also by  $\text{V}_2\text{O}_5$ ,  $\text{WO}_3$ ,  $\text{Bi}_2\text{O}_3$ ,  $\text{PbO}$  in the vapor. In fact, a rapid deterioration of chrome steel boiler supports has recently been analyzed to have been caused by  $\text{V}_2\text{O}_5$  in the combustion gases of a petroleum fuel containing traces of vanadium.

#### Liquid Metal Corrosion

With a liquid metal in contact with a solid metal the general types of reaction are similar to those of metal-gas reactions. That is, explained Cubicciotti, the solid metal or one of its constituents may dissolve in the liquid, the liquid may dissolve in the solid, or a compound of the liquid plus the solid may precipitate. In liquid metal heat transfer systems, there is the added complication of a non-isothermal system which gives rise to "mass transfer".

Liquid metals seem to find themselves classified as non-aggressive, aggressive, and very aggressive, depending on their aggressiveness to container metals. Examples of the three classes are (a) sodium and potassium, (b) lead, bismuth, and mercury, and (c) gallium and aluminum.

Gurinsky has recently reviewed the behavior of aggressive liquid metals. The work on mercury for boiler use showed that the solubility of iron in boiling mercury was small and little corrosion was expected; however, plant operation showed plugging of the cold zones by iron crystals. Apparently small amounts of iron dissolved in the hot zone of the boilers and precipitated in the colder zones and long-time operation led to plugging. Thus the problem became one of "mass transfer" rather than static solubility corrosion. Empirically it was found that small additions of titanium, zirconium, chromium, nickel, or aluminum reduced the mass transfer so that ferrous metals can be used for structural materials. The mechanism of corrosion inhibition by the added metals is by the formation of a surface compound between the iron and the added metal which reduces the rate of solution of the iron sufficiently that there is no tendency for it to precipitate in the cold zone.

Cubicciotti mentioned a heat transfer metal of recent interest—bismuth containing 0.1 percent uranium. This liquid is the fuel and coolant of the Brookhaven liquid metal reactor. It was found that small additions of titanium and magnesium markedly reduce the mass transfer rate of ferrous alloys.

The Brookhaven people studied the mechanism of the inhibition by zirconium in some detail and found that the zirconium reduced both the rate of solution of the iron into the bismuth and rate of precipitation of the iron from the bismuth in a cold zone. By forming a surface compound with the most active iron sites, the zirconium prevents the most active iron sites from dissolving and thus reduces the solution rate. In the cold zone, when the dissolved iron nucleates to form the first precipitate, the zirconium again forms compounds with the most active iron sites and hinders the addition of other iron atoms to those sites and hinders the nuclei from further growth. The small nuclei may well be carried by the flowing metal to the hot zone where they redissolve in preference to the walls of the container.



Co-chairmen of the High Temperature Symposium: (left to right) Dr. A. W. Searcy, University of California; Dr. N. K. Hiester, Stanford Research Institute; Dr. L. Brewer, University of California.

With zirconium the attack by oxygen in sodium is more difficult to control. Zirconium has a much greater avidity for oxygen than sodium. The equilibrium concentration of oxygen in sodium when exposed to zirconium plus zirconia is of the order of  $10^{-10}$  per cent. The problems associated with maintaining such a low oxygen concentration in a plant scale system are numerous. A method being explored at Atomics International is to use getters such as zirconium-titanium alloy. In addition they are conducting a study of the high temperature properties of zirconium containing oxygen to determine how detrimental oxygen is to the structural properties of zirconium.

#### All Agree: More Research

The foregoing pages present a miniature view of the open problems in high temperature technology confronting physicists, chemists and engineers. Some research scientists and engineers who have worked in this field for quite some time were a bit disappointed; they had the feeling that their colleagues were quietly exploring a number of high temperature possibilities for immediate use but could not discuss them because of their industrial competitive value. Apparently no one felt that Government restrictions played an important role in the withholding of information. Areas in which these researchers and engineers had hoped to pick up more data involved heat transfer media, and metal vapor and metal recovery systems. We are apparently not too far from these and other immediate industrial goals: new alloys for jet engines and turbine blades; higher temperatures for chemical processes such as hydrocarbon cracking, coal gasification, nitrogen fixation, and the direct reduction of metals from their ores.

But before some of these expected breakthroughs, all agree we need to amass huge quantities of physical data to check current conceptual schemes and to establish those that will ultimately form the spearhead of future developments.

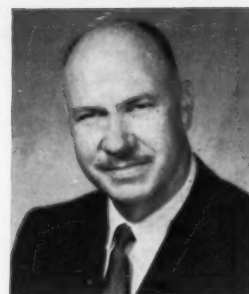
For example, Dr. H. Tracy Hall's work on diamond synthesis leads some to think that compounds now unknown, even in speculation, may exist miles under the surface of the earth, compounds created by the fantastic pressures and temperatures of millions of years ago. Digging down to uncover these may be a practical way to break the cyclical relationship between the need for better materials with which to contain the higher temperatures needed to develop these better, heat resistant alloys.

But perhaps the most intriguing cyclical relationship in high temperature technology was that put forth by Wolfgang Finkelburg. Ancient Greek philosophers reasoned that all matter was composed of four elements: earth, water, air and fire. He thinks them not too wrong if we make a small adjustment in definition and say that all matter has four states: solid, liquid, gaseous and plasma. For plasma can be considered the "fire" state of matter because of the definite change in physical characteristics exhibited by gases when raised to sufficiently high temperatures. And a major part of our understanding of the world in which we live as well as a host of new improved products and processes will stem from investigations into matter in the fourth state, matter at sun temperatures.



END

# Research Administration



**MERRITT A. WILLIAMSON**

*Dr. Williamson has recently been appointed Dean of the College of Engineering and Architecture at Pennsylvania State University. Dean Williamson will continue to write his monthly column on the administration of research.*

In last month's column we discussed selling upward; that is, selling to management. This month, let us talk about selling to other members of the corporate family who are on an equivalent level, such as the heads of marketing, manufacturing and finance.

In some company situations the R & D manager needs only to sell upward to keep his job. He must be personally satisfactory to the executive to whom he reports, and he may very well be required to work on the boss' pet projects. Such operations are often ridiculed within the company as "hobby shops". I do not mean to decry them, for they may have utility if they are well supported and if the director has the knack of arranging for all worthwhile ideas to originate with the boss. In spite of this, "hobby shops" do not generally tend to inspire love and understanding on the part of the other departments.

In order to sell, someone must buy, and the only reason for buying is to satisfy a need or desire. What do other departments of the company want? Each, of course wants something different. Marketing desires from the technical effort new products to sell, new uses for existing products, and reductions in production cost to permit outselling competition. Marketing men may look to the research and development department for technical advice to consumers to assist with a sale. It's a good idea for the R & D manager to plan his program to meet these needs and to set up his organization so that exchange of information with marketing people can take place readily.

If sales gets what it wants and is enthusiastic about the research and development operation, we have a very powerful ally, and one worth cultivating, since it is the source of our salaries and the money for investment in long-range projects. In industry there is no use for R & D unless there are sales. Let's acknowledge this and let's make sure the marketing men know what we can and are doing for them.

Is your program planned so as to have some new product or product improvement to release to your sales department at least once a year at the time of their annual sales meeting? Of course, you must have any such innovation in a state that production can follow through in short order. If your sales force is any good, it will want to pass advance information on to customers so they will delay purchase of competitors' items. But a word of warning is in order: we all recognize the dangers in acquainting enthusiastic salesmen with R & D projects at too early a stage. Another dan-

ger is that competitors will capitalize first on the proposed improvement. There's many a slip twixt concept and delivery! If your salesmen appreciate the dynamite they are handling, give them free access and start selling them early.

## **What Does Production Want From R & D?**

Now what does production or manufacturing desire from R & D? It wants many things, depending on the level of management, and what production goals are uppermost. For example, it wants:

- To make a new or superior product.
- Help in curing existing troubles in connection with materials, products and processes, and effort devoted to anticipating and preventing such troubles.
- New processes which are simpler and less expensive.
- Greater standardization to permit longer production runs with less down-time for retooling.
- Waste reduction and advice on use of valueless by-products.

The R & D program should include projects devoted to these aims. If help is given in these areas, manufacturing will aid and abet R & D efforts. Otherwise, R & D may be regarded as disrupting smooth production with trial runs and large-scale experiments.

Nothing is more annoying to the production man than to be in serious technical difficulty, and to be told by R & D that his problem must wait while some "harebrained", "blue-sky" idea is explored before any help can be made available. Such actions are not calculated to produce the kind of atmosphere conducive to "buying" even when good ideas are on hand, because there is too great an incentive on the part of the production man to show them up as impractical. In this area each R & D worker should be a good-will emissary, since selling at the working level is vital. No legislation, mandate, or directive can be as effective as the inauguration of group discussions of the best methods of selling R & D.

## **What Does Finance Want From R & D?**

Now what do the financial people want from the R & D department? I think that most of all they want to have their function in the company appreciated and their methods understood. Far too often there is almost a total lack of understanding between the accounting mind and that of the scientist or engineer. An antipathy between the two types frequently seems to exist, based on their different

philosophies and vocabularies. It is my belief that top management in most companies is far more understanding of the controller's language than of the R & D manager's.

I think the onus is on us in R & D to learn enough about budgets, burden and balances to be able to make our points in the accountant's language, and with an awareness of his point of view. Friendship and cooperation with the financial people will pay big dividends. We should sell them on our understanding and our willingness to conform to some of their arbitrary (to us) conventions. We should not forget that they have a record keeping and an historical function to perform for the company which is almost diametrically opposed to our outlook, which centers mainly on planning for the future. As a matter of fact, our R & D future may rest just as surely upon the "history" they write, as on our own technological advances. We can also sell the financial people on our gratitude for current data which helps us to operate in an efficient, economical and hence gratifying (to them) manner.

#### Devices and Vehicles for Communications

In lieu of a case this month, I am presenting the list of 48 devices and vehicles for communications which I promised in the May issue if your interest warranted it. I am indebted to Johnson and Johnson Company for permission to reprint this list which is taken from their manual entitled *Communications in Business and Industry*. This list is worthy of study and as you read through it, you might ask yourself if you are using these tools of communication as often as you might.

#### Wanted: More Discussion on the Servocomp Case

You will recall that the April case concerned the mythical Servocomp Company where a reorganization of the Research and Engineering Department was needed. The questions asked were: What unpleasant by-products might occur as a result of this problem? What is apt to happen in consequence? What is the source of the difficulty? With whom does the fault lie? What sound principles of management are violated and what principles and practices could be invoked?

The second part of the Servocomp Company problem (printed in the May issue) dealt with the day-to-day events showing how the reorganization was disclosed. The questions posed were: As R & D Director, how would you have handled this situation? What principles of sound management were violated? What principles were not invoked that should have been? What about communication? How can the Division heads get the R & D Director to be conscious of the morale element? What obligations do they have to do this, if any?

I have received some discussion of these two cases, but there should be much more. Remember that your name will be withheld on request, so you may say what you like. Give other readers of R/E the benefit of your opinion; try on the analyst's coat and have some fun wrestling with a problem you may be faced with someday, even if you cannot write a letter from actual experience.

Please address your replies to Dr. Merritt A. Williamson, c/o Research & Engineering, 77 South Street, Stamford, Conn. Your name will be withheld on request.

#### CHECK LIST OF DEVICES AND VEHICLES FOR COMMUNICATIONS

1. Committee assignments
2. Committee reports
3. Weekly or occasional department, board, committee, or staff meetings
4. Written minutes of such meetings
5. In-plant and departmental tours
6. Letter to employees
7. Standard operating procedures
8. Local newspapers
9. Task forces
10. Individual contacts
11. In-plant broadcasts
12. Written plans for the future
13. Counselling following merit rating
14. Use of understudies to attend meetings as substitute for principals
15. Manuals
16. Annual, project, stockholder and other reports
17. Memos and official notices
18. Signs: warnings, cautions
19. In-company organizations of engineers, foremen, accountants, etc.
20. Conferences with union officials, other department heads, and associates
21. Product specifications
22. Assignments of subordinates to work with employees of other sections or divisions
23. Social events
24. Radio programs—local or national
25. Exhibits of company advertising
26. Consultative supervision
27. Public actions of the company, its executives and employees
28. Junior or auxiliary boards
29. Employee and management surveys of opinion and attitude
30. Job rotation, transfers
31. Frequent counselling with subordinates
32. Bulletin board notices, posters, pictures, etc.
33. Conference leadership training
34. Liberal circulation of carbon copies of memos, announcements, etc.
35. Office wall charts
36. Column or frequent stories in company paper
37. Training classes of all kinds
38. Flow charts
39. Use of distribution lists and routing slips
40. Exhibits and open houses
41. Personnel practices
42. Visits to other operations, divisions, office, etc.
43. Films
44. Routing of written memos to all who should be informed
45. Reprints of executives' speeches or writings
46. Organization charts
47. Informal luncheon and dinner meetings
48. Formal grievance channels

# R/E views the books

## Transistor Electronics

BY LO, ENDRES, ZAWLES, WALDHAUER  
AND CHENG

*Reviewed by Fred C. Gabriel, Electronics Engineer, CGS Laboratories, Inc., Stamford, Conn.*

For fifty years engineers have been unable to see the electronics forest for the trees, or, more properly, for that one tree which has dominated the scene to the virtual exclusion of all others—the vacuum-tube. Indeed, until very recent times, it has been impossible to construct a plausible working definition of “electronics” without direct reference to that circuit element.

Now, with the introduction of the transistor, it becomes apparent that what we have been studying all this time is not electronics, after all, but merely vacuum-tube electronics; that the vacuum-tube, itself, is not fundamental, but is instead a particular invention in electronics; that our present definitions of that science must be broadened—not simply to embrace the transistor, but to include possible future developments.

With things as they are, such a definition is almost impossible to write. The dim glow of the electron tube's filament, although generating enough heat to power a huge and far reaching technology, does not yield enough light to let us see properly the boundaries and the details of that technology. Now books must be re-written, and ideas expanded. In spite of the loudly publicized advantages in power economy, ruggedness, compactness and reliability which it surely offers, this may well be the most important contribution of the transistor to today's engineer.

The authors of *Transistor Electronics*, in leaving behind the vacuum-tube background in which they must have matured as engineers, make a remarkable presentation of the transistor for itself. Although references to the tube are made, as they must be for the sake of intelligibility to a present-day audience, the structure of the text is not founded upon vacuum-tube circuitry. It stands alone. To the average engineer “amplification is what a vacuum tube does”. But the present authors have been successful in generalizing the matter of amplification as well as many other heretofore vacuum-tube concepts. And as practicing engineers, they have included in their book much original and previously unpublished material.

The organization of the book is conventional in that it proceeds from a scrutiny of the transistor itself to the application of it in circuits of varying degrees of complexity. For the transistor, as for the tube, three basic amplifier configurations are possible; the text discusses each of these, and, without prejudice, allows the advantages and limitations of each to become apparent. A chapter on bias circuits explains how the electrical operating point is established and prepares the reader for the more advanced chapters on low-frequency amplifiers, power amplifiers and high-frequency amplifiers. There are also chapters on oscillators, modulation and demodulation and pulse circuits. Although most of these have fairly close counterparts in the vacuum-tube realm, the transistor frequently is seen to display advantages which make it the “natural” choice for certain electronic tasks.

The transistor clearly is off to a running start. If the present pace continues, one cannot help but wonder how many generations of engineers will have passed before chicken-or-the-egg arguments arise about the tube, the transistor and which really came first.

*Prentice-Hall, 521 pages, \$12.00.*

## The Economics of Consumption

BY WILLARD W. COCHRAN  
AND CAROLYN BELL SHAW

*Reviewed by John Rivoire, Manager of Market Research, Westvaco Mineral Products Div., Food Machinery & Chemical Corp.*

Consumption economics is a vague and somewhat confusing term which means many things to many people. The authors of this book have set themselves the task of bringing some order out of the chaos and making a start toward a genuine science of consumption economics.

As the authors note in their preface, many texts already exist which aspire to cover some phase of consumer economic problems. Among them are “numerous volumes focusing on personal finances, consumer education, and various aspects of buymanship”, but, they say, “few that concentrate on the economics of consumption”. This, in their own words, is what they propose to do: “We have felt the need of a text that grows out of the main

stream of economic thinking, that employs analytical methods from modern economics, and that with problems amenable to solutions by economic analyses, we have felt the need of a text that describes and analyzes the decision making of households . . .” This volume is designed primarily as a textbook for college courses in consumer economics which would follow a course in elementary economic analysis.

The book is organized in five parts. The first introductory part deals with some basic definitions and relationships. It is followed by a section on the theory of consumer behavior which addresses itself to the problem of choice, the two major methods of solving the problem on a theoretical level (utility and indifference) and some of the values and applications of the theory.

Part three is an elaboration of the expenditure approach. This part deals with some historical observations on spending patterns, recent research and analysis, and the current situation and thinking on household expenditure patterns. Part three, “The Consumer in the Market”, is concerned with what happens in the market place. This is a fairly straightforward presentation of demand and price analysis, with some consideration of the role of government programs. The final section is on “The Consumer Outside the Market”. This deals with collective consumption such as services supplied by the government and other institutional aspects of the economy as they impinge on the consumer, and with economic policy.

This book is of greatest interest to economists and marketing people. It says little that is new but rearranges some of the recent thinking on consumer economics. Research and development people will probably be most interested in the chapters describing the economic system but similar descriptions are available elsewhere. The principal value of this book, other than to students or professional economists, appears to be in supplying valuable general background and a framework for thinking about economic problems and policies on both the individual and the social level. It is to the credit of the authors that they have presented a well-organized, fairly complete and unbiased picture of the field and have perhaps gone a little way toward a better definition of a heterogeneous and sometimes baffling field of inquiry. *McGraw-Hill Publishing Co., New York, N. Y., 470 pages, \$6.50.*

## Reference Texts

**High Temperature Technology**, edited by I. E. Campbell. John Wiley & Sons, Inc., New York, N.Y., 526 pages, \$15.00.

Thirty-five authorities have contributed to an extensive summary of recent developments in high temperature technology. In the first major section of the book, "Materials", the authors cover metals, oxides, properties of carbon and graphite at high temperatures, carbides, borides, silicides, nitrides, sulfides, and cermets. The second section, "Methods", deals with sintering of metallic and nonmetallic refractory materials, means of achieving high temperatures, resistance and induction-heated furnaces, arc furnaces, and others. The last section, "Measurements", includes temperature and its measurement, mechanical properties, physical properties, and special techniques. A very worthwhile addition to your reference library.

**Workshop for Management**, 500 pages, \$19.00 (10-day free examination basis). Management Publishing Corp., 22 W. Putnam Ave., Greenwich, Conn.

The Eighth Annual Meeting of the Systems & Procedures Association of America has produced an organized, illustrated book from the meetings, panels, seminars, talks of the management workshop. An aid for business management for solving operating problems and cutting overhead costs. Special emphasis on electronics and operations research.

**Copper Wire Tables**, 4th Edition, \$0.30. NBS Circular 31, order from Government Printing Office, Washington 25, D. C.

All data in this booklet is expressed in both English and metric units. The American Wire Gauge as presented in this publication is formed by geometrical progression. The circular also contains a number of simple formulas for computing data for any size wire. In this revision the tables have been extended to 50 gage and up to 200°C.

**Units and Systems of Weights and Measures** by Lewis V. Judson, 29 pages, \$0.25. NBS Circular 570, order from Government Printing Office, Washington 25, D. C.

Millions of daily industrial operations and commercial transactions depend on a uniform and convenient system of weights and measures. General information on both the customary and metric systems of weights and measures is included in this circular.

**Compilation of ASTM standards on petroleum Products and Lubricants**, 984 pages, cloth covers: \$7.15, paper covers: \$6.50. Order from: American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

This compilation includes tentative and standard methods of test, specifications, definitions of terms and classifications of petroleum products and lubricants, with many proposed methods of test. Included

are two new tentative methods of test for lubricating qualities of graphites and trace concentrations of tetraethyllead in primary reference.

**The Production and Properties of Graphite for Reactors** by L. M. Currie, V. C. Hamister and H. G. MacPherson. Published by the National Carbon Co., 61 pages.

Originally presented at the UN conference on Atomic Energy in Geneva, this monograph discusses reactor graphite, its production and processing variations, and its chemical, mechanical and physical properties. Also contains a list of 62 references.

**Zirconium Technology and Economics**. Published by the Atomic Industrial Forum, Inc., 260 Madison Ave., N. Y. 16, N. Y. 125 pages, paper bound. \$3.00

Based on proceedings of a two day Forum meeting, this report includes papers and discussions on chemistry and production of metallic zirconium; fabrication, properties, corrosion behaviour, alloys, supply of raw and refined materials, commercial products available and future AEC and industrial requirements.

**A Palimpsest on the Electronic Analog Art**. Edited by H. M. Paynter, printed by G. A. Philbrick Researches, Inc., 230 Contress St., Boston, Mass. 270 pages, paper bound. \$1.00

A collection of reprints of papers in the electronic analogue field that have appeared in the technical press in the past several years. Not intended as a definitive or exhaustive treatment, the collection stresses introductory and fundamental material of use to practitioners, teachers and students.

**Second Annual Computer Applications Symposium**, Published by the Armour Research Foundation, CAS 2, Technology Center, Chicago 16, Ill. \$3.00

The annual Symposium covers applications of computers and data processing machines to business and management problems as well as to engineering and research problems. The Proceedings were prepared from a stenographic transcript of the Symposium and include the discussion following each paper.

**Two reports on aeronautical telecommunication published by Radio Technical Commission for Aeronautics**, 16th & Constitution Ave., NW, Washington 25, D. C.

Paper 225-55/DO-69 (\$0.30) recommends minimum performance standards for airborne VOR receivers operating in the 108-118Mc range. This report urges compliance with its standards to assure that equipment will perform the intended function satisfactorily under all conditions normally encountered in routine aeronautical operations. Paper 196-55/DO-68 (\$0.65) is a report on a study conducted by SC-69 on remoting of long range radar displays. Types of possible systems, costs and capabilities of each, and methods are discussed.

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# Research Reports

Reports in this section may be obtained directly from the Office of Technical Services, U.S. Dept. of Commerce, Washington, D.C., unless another source is stated.

## Boron Effects

The influence of boron, alone or with titanium, on the high-temperature strength of a 13 Cr—15 Ni—2 Mo—0.6 Ti alloy is discussed in this study. It was found in the research that boron markedly increases creep-rupture strength by an alloying effect involving either solid solution strengthening or, more probably, a strain-ageing type reaction under the slow strain rates and small deformations of creep-rupture conditions.

INVESTIGATION OF THE INFLUENCE OF BORON AND TITANIUM ON THE HIGH-TEMPERATURE PROPERTIES OF CR-NI-MO-FE AUSTENITIC ALLOYS, PB 121101, 72 pages, \$2.00.

## Magnetic Cores

Two reports. The first traces the chronological development of magnetic core logical circuitry and its application to digital computers. The relative advantages, disadvantages and principles of operation of various types of magnetic core shift registers are presented.

FERROMAGNETIC CORE LOGICAL CIRCUITRY AND ITS APPLICATION TO DIGITAL COMPUTERS, PB 111954, 59 pages, \$1.50.

The fact that a magnetic core requires a given number of volt seconds to be driven from saturation in one direction to saturation in the other is utilized to build a dividing circuit. It employs switching transistors and a single high remanence magnetic core, and provides an output voltage whose average value is the quotient, with the correct sign, of two input voltages.

ANALOGUE COMPUTATION OF QUOTIENTS AND FUNCTIONS CONTAINING QUOTIENTS USING MAGNETIC CORES, PB 111969, 13 pages, \$0.50.

## Fluorine Compounds

Research at Cornell University on fluorine compounds was done in three principle areas—radical addition reactions of perhalo olefins, condensation reactions of perhalo compounds, and synthesis of fluorinated vinyl ethers.

BASIC STUDIES ON THE CHEMISTRY OF FLUORINE COMPOUNDS, PB 111959, 148 pages, \$3.75.

## Antioxidants for Greases

Amines are better inhibitors of oxidation in greases than any other types tested in an Army Ordnance Corps research program to develop compounds for this purpose. Outstanding among the amines are

the phenylenediamines. The sulfur compounds used in the study did not show anything exceptional as inhibitors, but three of the substituted phenols were able to inhibit oxidation in some types of greases for more than 500 hours.

ANTIOXIDANTS FOR GREASES, PB 121017, 34 pages, \$1.00.

## Modulus Fibrous Glasses

A 50% increase in modulus of elasticity of fibrous glass by the continuous formation of fibers of a calcium aluminate glass in a small textile glass bushing is reported. Resistance of these glasses to chemical attack by water and water vapor is much less than that of commercially produced textile fibrous glass. The glasses are resistant to hydrofluoric acid but are completely soluble in hydrochloric acid. Their dielectric constants are higher than that of present textile glass, and the loss tangents are approximately the same.

THE DEVELOPMENT OF FIBROUS GLASSES HAVING HIGH ELASTIC MODULI, PB 111789, 112 pages, \$3.00.

## Electronics Research

Two reports. In the first, emphasis was placed on the task of bonding copper foil to silicone laminates with some success. The best adhesive system used was a rubber-phenolic-epoxy type. Several new rubber-phenolic type adhesives were developed. ADHESIVE FOR COMPOSITE MATERIAL USED IN PRINTED CIRCUITRY, PB 111869, 41 pages, \$1.25.

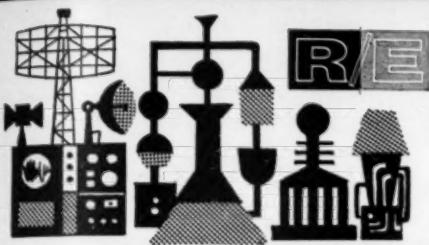
The problem of determining the role that the space charge of large beam current densities plays over field free drift regions of a velocity modulated electron beam is investigated in this report. Particularly studied is the space charge "debunching". DEBUNCHING IN U-H-F VELOCITY-MODULATED HIGH DENSITY ELECTRON BEAMS, PB 111799, 112 pages, \$3.00.

## Particles Dispersion

The dispersion of material particles in a turbulent field is discussed in this report. Particles studied are those whose size and inertia are such that it cannot be assumed that they will follow exactly the fluctuations of the fluid elements with which they are associated. The turbulent field is assumed to be stationary, homogeneous, and isotropic. Stationary, extraneous force fields for the particles may exist. TURBULENT DISPERSION OF DYNAMIC PARTICLES, PB 111958, 24 pages, \$0.75.

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## PRODUCT PORTFOLIO

Components • Chemicals • Literature  
Materials • Instruments • Equipment

### High-Temperature Pots 20

and components that have operating temperatures from  $-55^{\circ}\text{C}$ ,  $175^{\circ}\text{C}$ , or  $225^{\circ}\text{C}$  includes wire-wound potentiometers in both single and multi-turn types. In addition to wire-wound, rotary and trimmer deposited film types too. These units have a load life at high temperatures up to and in excess of 500 hours and a rotational life at high temperatures up to 500,000 cycles, or its equivalent for multiturn units. Fairchild Controls Corp., Components Div., 225 Park Ave., Hicksville, N. Y.

### Translucent Tarp 21

material has many uses in protecting lab equipment during field tests. Made of loose mesh high-strength Celanese rayon between two vinyl coatings. Lets enough light through to avoid use of lights in daytime.

Herculite Protective Fabrics, Inc., 140 Little St., Belleville, N. J.

### Antistatic Plastic 22

"Homalite 141" has inherent antistatic qualities which prevent the accumulation of static electricity on its surface. This material is ideal for sensitive instruments where static affects accuracy. The Homalite Corp., 11-13 Brookside Dr., Wilmington 4, Del.

### Spectroscopic Powders 23

and electrodes are presented in a new 16-page catalog. The major portion deals with 37 special grade preformed electrodes. Also described are special grade 12-inch electrodes, and powders, and the regular grade electrodes that can be used where spectroscopic requirements do not demand materials of the highest purity for material analysis.

National Carbon Co., 30 E. 42 St., New York 17, N. Y.

### Torque Converters 24

in a range of 100 to 1000 horsepower. This has been accomplished with six basic sizes which include 17 power capacities in closely spaced ranges for exact matching with engines and electric motors for plant application.

National Supply Co., Two Gateway Center, Pittsburgh, Pa.

### Vacuum Gage 25

gives direct, continuous pressure readings from 1 to 2000 microns Hg. Measures on two scales the total pressure of condensable vapors and permanent gases in a vacuum system. A new sensing tube greatly reduces zero drift, solving one of the greatest problems in previous hot-wire gages.

Consolidated Electrodynamics Corp., 1775 Mt. Read Blvd., Rochester, N. Y.

### Resistor-Capacitor 26

combination that requires only the space of a tubular capacitor alone is designed to permit greater performance and cost saving in applications where space is at a premium. Particularly useful for antenna line applications.

Centralab Div., Globe-Union Inc., 900 E. Keefe Ave., Milwaukee 1, Wis.

### Radioisotopes 27

bulletin describes many new isotopes, some of which are offered for the first time to industrial and scientific laboratories. Notably among these is the long-lived isotope of aluminum,  $\text{Al}^{26}$ . They are made by accelerators.

Nuclear Science and Engineering Corp., Box 10901, Pittsburgh 36, Pa.

### High-Impact Sheet 29

copolymer of styrene has great impact strength—even at temperatures as low as  $-40^{\circ}\text{F}$ . It also has high tensile and flexural strength, and a relatively high heat distortion point. Its chemical resistance is exceptional, particularly to acids and alkalis. For a wide range of industrial applications, including machine housings, tote boxes, photo trays and many automotive applications, such as panels, liners, and seat skirts.

Campco Div., Chicago Molded Products Corp., 2712 N. Normandy Ave., Chicago 35, Ill.

### What's New for the Lab 30

just off the press. Among new items illustrated and described are: a furnace, dispenser for metal-sensitive liquids, glassware, adjustable speed stirrer, Teflon labware, miniature temperature recorder, polyethylene pump, electronic

thermometer, plus many other items. Scientific Glass Apparatus Co., Inc., Bloomfield, N.J.

### Silicon Rectifiers 31

designed to meet stringent military requirements are designated IN537 and IN538. Both are rated at a maximum d-c output current of 250m at  $150^{\circ}\text{C}$ . A prime feature of the new rectifiers is that high current loads can be carried without the use of any heat sink.

General Electric Semiconductor

Products, Electronics Park, Syracuse, N.Y.

### Phenolic Laminate 32

has good electrical properties, low cold flow, low moisture absorption, good dielectric strength (both perpendicular and parallel to the laminations), and ease of hot punching and shearing.

National Vulcanized Fibre Co., 1056 Beech St., Wilmington, Del.

### Self-Tapping Studs 33

a double-ended stud that cuts its own thread when driven in an ordinary drilled hole and locks securely in the same operation. Hole tolerance is not critical, and no special hole preparation is needed.

Pheoll Manufacturing Co., 5720 Roosevelt Rd., Chicago 50, Ill.

### Military Type Transistor 34

is a germanium p-n-p junction transistor designed for electronic equipment requiring extreme reliability at high temperatures and under severe environmental conditions. Rated and tested for operation up to  $75^{\circ}\text{C}$ , the 2N200 can dissipate up to 350mw.

Transistron Electronic Corp. Melrose 76, Mass.

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**Torque Watch 35**

has new design features, based on user reactions to the first model. The length of the outer shell of the instrument has been increased to 1-3/16 inches. For greater versatility, the chuck has been redesigned to allow torque measurement on devices with 1/4-inch diameter shaft as short as 1/16 inch. Furnished in two ranges: 0.01-1.2 and 1-20 ounce-inches. *Waters Manufacturing Inc., Box 368, So. Sudbury, Mass.*

**100-Point Switch 37**

is a two-motion, 100-point step-by-step switch that operates over 10 points in a primary direction, and 10 points in a secondary direction. It can be used for searching through 100 four-wire circuits to find a particular circuit, for selecting a particular circuit from among 100 circuits, or for performing consecutive operations in 100 separate circuits such as automatic controls. *Industrial Sales, Telephone Div., Stromberg-Carlson Co., Rochester 3, N.Y.*

**Radioactive Phenol 38**

Phenol-C<sup>14</sup> (uniformly labelled) useful as a tracer or as a synthetic intermediate in the study of plant and animal chemistry and will be helpful in the analysis of many commercial products, e.g., insecticides, medicinals, plastics. *Nuclear Instrument and Chemical Corp., 229 W. Erie St., Chicago 10, Ill.*

**Printed Circuit Protective 39**

a new nickel plating process specifically for use with rhodium produces superhard and ductile, compressively stressed nickel coatings. Known as "Lectro-Nic", the new process counteracts rhodium electroplate's inherent tendency to cracking and peeling, when used as an undercoat. Of particular interest to printed circuit manufacturers because it eliminates the peeling and curling common in printed circuits and other precision components which have been plated with ordinary tensile stressed metals. *Sel-Rez Precious Metals, Inc., 229 Main St., Belleville 9, N.J.*

**Shaft Seal 40**

for corrosive and high-temperature service has a sealing member of Teflon. Made in various types for handling acids and corrosives. *Crane Packing Co., 6400 Oakton St., Morton Grove, Ill.*

**Digital Voltmeters 41**

especially designed for applications demanding continuous precision operation give three complete readings per second with automatic polarity indication. Absolute accuracy:  $\pm 0.01\%$  of value read,

or  $\pm$  one digit. Input impedance is 11 megohms. Available in three-, four- and five-digit models.

*Non-Linear Systems, Inc., Del Mar Airport, Del Mar, Calif.*

**Impregnated Teflon Felt 42**

for resilient gaskets and gasket material is designed for use in severe physical and chemical environments where other gasket materials fail. Withstands ambient temperatures from minus 320°F to plus 550°F.

*Shamban Engineering Co., 11617 W. Jefferson Blvd., Culver City, Calif.*

**Rotary Solenoid 43**

weighs 1 1/2 ounces and has a diameter of one inch. Starting torque is 0.2 lb-in. based on ampere-turns for normally intermittent duty cycle and rotary stroke of 45 degrees. Standard rotary strokes for the new solenoid are 25, 35 and 45 degrees, either clockwise or counter-clockwise rotation.

*G. H. Leland, Inc., 123 Webster St., Dayton, Ohio*

**Transistor Transformers 44**

for transistor circuit applications, feature very small size, high efficiency nickel alloy cores, bobbin wound windings and flexible coded leads. They have open type mountings.

*Merit Coil Products Co., Inc., 4427 N. Clark St., Chicago 11, Ill.*

**Rotary Switch 45**

is 1 3/4" in diameter by 1-11/16" in depth. It is available with three poles on a single deck and may be ordered with as many as nine positions per pole with shorting type action, or five positions per pole with non-shortening type action. Rotor and stator material is XXXP phenolic.

*Daven Co., 580 W. Mt. Pleasant Ave., Livingston, N.J.*

**Aluminum Information 46**

in the form of a compact monthly publication covering all aluminum news, is being made available to the entire metal-working industry. Contains 50 to 60 reviews of articles relating to aluminum that have been published in the technical press the preceding 30-60 days. To obtain this material, about 300 different periodicals are examined regularly.

*Desk ES, Reynolds Metals Co., 2500 S. Third St., Louisville 1, Ky.*

**Platen Lab Press 47**

is available in platen sizes from 8" x 8" to 18 1/2" x 18 1/2" and with ram capacity from 20 to 125 tons.

*Pasadena Hydraulics, Inc., 273 North Hill Ave., Pasadena, Calif.*

**Sine-Cosine Converter 48**

analog to digital type. The input shaft is scaled at 360° per revolution full-scale input. No intermediate gearing is necessary. Coding is in continuous serial binary form in increments of 2-0 for values of the functions from zero to one.

*Librascope, Inc., Glendale 1, Calif.*

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with increased compatibility with many organic chemicals. This greater solubility of L-41 permits broader usage of silicones in many petroleum and resin-based products in which "DiMethyl Silicone" oils are completely insoluble.

*Silicones Div., Union Carbide and Carbon Corp., 30 E. 42 St., New York 17, N.Y.*

**Vacuum Tubes 50**

for black-and-white and color TV sets include a general-purpose, multi-unit tube (6CH8) intended for a wide variety of applications in black-and-white and color TV receivers, and a beam power tube (6CB5-A) designed especially for use in color TV receivers.

*RCA Tube Division, Harrison, N.J.*

**Instruments 51**

and test equipment catalog (87 pages) includes 800 panel meters of all kinds and sizes, capacitor testers, oscilloscopes, temperature meters and many other instruments used throughout industry. Handy thumb guides make reference to the book's major sections and price lists easy.

*Simpson Electric Co., 5200 W. Kinzie St., Chicago 44, Ill.*

**Dual-Rated Breaker 52**

for the protection of equipment designed to operate on either of two different voltages—such as 6 and 12v d-c or 110 and 220v a-c with separate load connections for each rating. Although most of the ratings supplied to date have had current ratios of 2 to 1, the company can make breakers with current ratios of up to 4 to 1.

*Heinemann Electric Co., Dept. 777, 99 Plum Street, Trenton 2, N.J.*

**Light Pulses 53**

in the microsecond range and modulated light beams at variable frequencies from d-c through the video region are easily obtained with a high speed light pulsing and modulation apparatus. Applications include use in sound-on-film, video-on-film, polarimetry, densitometry, photography, photometry, interferometry and measurement of semiconductor parameters.

*Baird Associates, Inc., 33 University Rd., Cambridge 38, Mass.*

**Remote Pipette****54**

for handling radioactive and dangerously toxic liquids. The pipette is supported more than three feet from the operator, yet the clear volume calibration is easily visible from that distance. *The Atomic Center, Inc., 489 Fifth Ave., New York 17, N.Y.*

**Power Resistor****55**

for printed circuits and advanced miniaturization designs where the stability and overload capacity of wire-wound resistors are essential. A miniature 3-watt axial lead type. Resistance values to 6500 ohms,  $\pm 5\%$  tolerance. *Ward Leonard Electric Co., Mount Vernon, N.Y.*

**Transistor Capacitors****56**

having the same capacity but only  $\frac{1}{2}$  to  $\frac{1}{4}$  the size previously used in transistorized and printed circuit, may be manufactured from new "K" gaged mica. "K" gaging is a new electronic method of accurately gaging mica film which permits utilizing smaller area mica to obtain pre-determined capacity. *Perfection Mica Co., 20 N. Wacker Dr., Chicago 6, Ill.*

**Non-Contact Thickness Gages****58**

of Beta radiation design for the continuous measurement and production control of sheet paper and board, plastics, rubber, metal foil and strip, coatings and laminates. Are designed and engineered for applications requiring superior quality control, and offer high standards of accuracy and performance. *Nuclear Corp. of America, Inc., Suite 4219, Empire State Bldg., New York 1, N.Y.*

**Electrochemical****59**

bulletins on sodium and potassium chlorate, ammonium and potassium perchlorate and manganese dioxide are intended for use by manufacturers of weed killers and defoliants, matches and fireworks, rockets and guided missiles, flares and fuses. The bulletin on manganese dioxide was prepared for battery manufacturers. *American Potash & Chemical Corp., Los Angeles (Vernon), Calif.*

**Digital Recorder****60**

provides a simple and economical means for simultaneous recording "on" or "off" voltage phenomena appearing on as many as 45 channels at sampling rates as high as 2500 per second. Typical applications include monitoring of operations and data in large-scale digital computers and other data-processing systems for business or engineering. *Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, N.Y.*

**Printed-Circuit Filters****61**

of subminiature size designed for i-f amplifiers for printed circuit use. These units are temperature compensated to 0.15% from  $-55^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ . *Burnell & Co., Inc., 45 Warburton Ave., Yonkers 2, N.Y.*

**Resolvers****63**

bulletin gives specifications and characteristics of 36 precision resolvers available in standard frame sizes—10, 11, 15 and 23. Are offered from coarse  $\pm 0.2\%$  to precision  $\pm 0.05\%$ . They provide accurate solutions to problems encountered in high precision phase shafting, data transmission, industrial process controls, rectangular to polar coordinate transformations and rectangular coordinate rotations. *Norden-Ketay Corp., 99 Park Ave., New York, N.Y.*

**Corrosion Tester****64**

is a new instrument to rapidly measure the rate of corrosion in all types of metals subjected to the corrosive effects of various liquids or gases. In a few hours, predicts the amount of corrosion that may take place in five or 10 years of field use. *Labline, Inc., 3070-82 W. Grand Ave., Chicago 22, Ill.*

**Servo Motor Generator****65**

a new size 11 unit features all stainless steel construction, small size and light weight. This unit measures 1.062" diameter and  $2\frac{1}{2}$ " long and weighs 6 ounces. Its operating temperature range is  $-54^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ . For application in airborne servo systems, the servo motor will deliver 0.60 oz.-in. torque at stall and its no-load speed is 5600. *Kearfott Co., Inc., Little Falls, N.J.*

**Power Supplies****66**

feature germanium rectifiers, making for higher efficiency, compact design, and longer life in four new space-saving rack model regulated d-c power supplies. Have a panel height of  $5\frac{1}{4}$ " and thus allow added rack space for other components. Rated at 400ma, have a range of 125-325 vd-c for Models 481 and 481M, and 325-525 vd-c for Models 482 and 482M. *Lambda Electronics Corp., 11-11 131st St., College Point 56, N.Y.*

**Precision Hardware****67**

made to extremely close tolerances. Hardware is made exactly to customer specifications from aluminum, brass, bronze and different types of plated and unplated carbon, alloy and stainless steels. *Aero Supply Mfg. Co., Inc., Corry, Pa.*

**Function Generator****68**

which will relate any non-linear function to a shaft rotation. The "Non-Linear Function Generator" is easily and quickly adjustable to provide any mathematical or empirical function including those with multiple slope reversals. Uses are in the non-linear servo field, in computers, and for the correction of non-linear transducers. *Perkin-Elmer Corp., Norwalk, Conn.*

**Printed Circuit Kit****69**

for quick and easy designing of prototype models. A completely etched electrical circuit ready for assembly may be had in about 30 minutes. At least a dozen circuits may be produced with the materials in the kit. *Photocircuits Corp., Glen Cove, New York*

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**Petroleum Sulfonates****71**

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developed especially for very high speed drives. Spindle speeds in excess of 100,000 rpm can be maintained for extended periods over small pulleys without apparent damage to the belt in an oily atmosphere at high temperatures. *Russell Manufacturing Co., 42 E. Main St., Middletown, Conn.*

**Portable High Vac Unit****73**

for general lab work, for pilot plant operations and small scale production. Designed to attain absolute pressures as low as  $10^{-6}$  mm Hg. The unit is recommended for use in exhausting 10 to 15 cu. ft. chambers for vacuum distillation, impregnation, coating, degassing, stress relieving, etc. *Kinney Manufacturing Div., The New York Air Brake Co., Boston, Mass.*

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*Minnesota Mining and Mfg. Co.,*  
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Here's a brief review of last month's advertising in RESEARCH & ENGINEERING as a service to readers.

## High Vacuum Components 100

including vacuum gages, diffusion pumps and rotary gas ballast pumps are designed to increase the productivity of vacuum systems. Other high vacuum products of this firm include: analyzers, dehydrators, freeze driers, impregnators, metallizers and valves.

*National Research Corp.,*  
Newton Highlands 61, Mass.

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have undergone 13 tests including Spectograph tests, chemical analyses,

Zyglo tests, and are available in wide variety of sizes, grades and materials.

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## Rare Earths 102

as catalysts have great commercial possibilities, and are assuming an important place in the operations of many industries. Cerium oxide has revolutionized glass polishing practices, and earth chloride is used extensively in the textile industry, the metal industry and in the manufacturer of paint and ink.

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## Nuclear Research Reactors 103

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## Electron Microscope 105

solves problems of quality control, product improvement and new product development as well as those of fundamental research. A new booklet, "The Electron Microscope in Science and In-

dustry", cites actual case histories and provides revealing examples of the microscope at work.

*Radio Corp. of America, Dept. G-281,*  
Camden, New Jersey

## Plant Size Reactors 106

with lab-equipment precision already have given superior performance in many atomic energy projects. Standard or specially designed reactors are available featuring confined gasket closures.

*Autoclave Engineers,*  
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## Straits Tin 107

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## Storage Batteries 109

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